

# THE NATURE OF SUSTAINABLE ENERGY ACCESS TRANSITIONS: REALITIES AND POSSIBILITIES FOR LAGOS, NIGERIA

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I, Elusiyan Olufemi Eludoyin, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the work.





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# Abstract

This thesis is an investigation, both theoretical and empirical, into how the developing country energy poor can sustainably transition to modern energy services. This question is at the forefront of global issues as signified with Sustainable Development Goal 7 (SDG7); which includes the target of ensuring universal energy access for all. Global statistics on energy poverty show that after more than 50 years of experience, limited progress has been achieved in providing the unserved with modern energy services. A conceptual framework is developed to graphically explain different kinds of household transitions as related to sustainability; drawing on empirical evidence, and theories of household energy transitions in developing countries, consumer decision-making, and sustainable livelihoods. Six months of field research conducted in two stages is undertaken in an interesting case from Lagos, Nigeria, with the aim of understanding the existence and scope of the drivers of household energy use, change, and sustainability. The case provides evidence to suggest that sustainable transitions take place when an accessible modern energy form is deemed a necessity because the traditional alternative is no longer accessible, under strong influence by developments in a household's organisation of daily life. The Long-range Energy Alternatives Planning tool (LEAP) was used to develop an innovative model of household energy demand for Lagos state to explore medium to long term transition possibilities. Results suggest, among others, that energy access should prioritise the facilitation of energy supply that can alleviate the need for energy stacking, because energy stacking can lead to unintended policy outcomes and wasted resources. The thesis concludes that if SDG7 desires to displace traditional energy services, then as opposed to using modern energy to change people's lives, the international community needs to change people's lives to use modern energy services.



# Impact Statement

There are a number of ways in which the outputs of this research can have an impact on the field of energy and development, both in academic and non-academic domains, and across multiple scales of work to address the energy poverty problem.

Of particular benefit to academic scholarship in this field is the dissemination of this thesis' original contributions. Work is ongoing to publish key sections of this thesis in peer-reviewed journals. The concept developed to explain the sustainability of household energy transitions and the insights from the case study of rural Lagos offer new ways of thinking about efforts to address energy poverty, and the indicators of success. The model developed to examine scenarios of household energy demand in Lagos, Nigeria adds another useful and distinct way of exploring energy policy/strategy pitfalls and opportunities in developing countries, which can be adopted and developed further in research and in practice, to form a useful component of the policy development process.

The outputs of work undertaken in the field and the model of household energy demand are directly relevant to Lagos and Nigeria. There is an opportunity for public policy and development planning to be shaped by observations highlighted in this research as being significant for sustainable household energy transitions at the state and national levels. On a global scale, the insights obtained from the field suggest the need for more ambition from key proponents and stakeholders in the energy sector, if energy access solutions are to be meaningful and sustainable. Transdisciplinary work in conjunction with practitioners to obtain further evidence on the key facilitators identified, will be an important tool for shaping high-level discussions on the universal energy access target of Sustainable Development Goal 7.

At the local level, and particularly important, is the dissemination of findings with relevant stakeholders of the communities included for fieldwork. There is an opportunity for the rural locals to benefit from learning about the determinants of positive change in their communities and surrounding regions. An important potential impact of this research, is providing information and support in developing the organisational structures the communities can draw on to benefit and protect their interests during periods of change.



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## Chapter 1

# Introduction

## 1.1 The challenge of universal energy access

This thesis is an investigation into how the global energy poor can sustainably transition from the use of traditional energy services to modern energy services. With 1.06 billion and 3.04 billion of the global population lacking access to electricity and relying on solid fuels for their cooking and heating needs (World Bank 2017*a*) — which combine to impede their immediate and long-term welfare (GEA 2012) — this transition is of critical importance. The inclusion of energy poverty in the Sustainable Development Goals (SDGs) as one of three dimensions of SDG7 highlights the global attention being given to the issue; which began with the United Nation’s launch of Sustainable Energy for All (SE4ALL) in 2011, after 50 years of practice and research in a field that achieved limited progress.

The energy poverty portion of SDG7 stipulates the achievement of universal access to affordable, reliable and modern energy services by 2030. The gravity of this challenge is not least highlighted by the fact that in the 20 years till 2010, population growth meant that the net effects of energy access consisted of only 128 million less people without access to electricity, while there was no change in the number of people relying on solid fuels (Banerjee et al. 2013); or indeed, that since the establishment of SE4ALL progress has been said to be falling “dismally short of the pace required to meet the global objective” by the World Bank and IEA (IEA & World Bank 2015). As at 2010 there was an estimated \$40.3 billion annual shortfall in funding requirements (Banerjee et al. 2013). 2013 estimates suggest additional financing requirements between \$65 billion to \$86 billion annually to meet the 2030 goal, in the presence of dedicated policy to reduce costs (World Bank 2017*a*). Most recent forecasts envision 674 million people globally will still be without electricity access by 2030, and 2.3 billion still without access to clean cooking by that year (IEA 2017).

The reality is that energy poverty in developing countries is a complex problem characterised by: varying regional, country, and local contexts whose common feature is their unsuitability to conventional forms of energy access; the potential for multiple, and often, unproven technical and business solutions; and the presence of multiple dimensions for assessing welfare impact, amongst others — which make designing and implementing programmes for the achievement of sustainable progress particularly challenging in regions with limited resources to address their many development needs. Some countries have made significant strides in recent decades providing their energy poor populations with access to modern energy services; particularly countries in Developing Asia such as China and India, but even they still have existing energy poverty concerns (World Bank 2017*a*). Sub-Saharan Africa (SSA) represents the region with the greatest energy poverty burden globally hosting circa 587 million (63 % of the continent’s population) of the 1.06 billion people without access to electricity worldwide, and 807 million (88 % of the continent’s population) of the 3.04 billion

people without access to clean cooking (World Bank 2017*a*).

Critically, out of the 674 million the IEA expect to be without access to electricity by 2030, 600 million reside in SSA countries suggesting that population growth will outstrip any gains in electricity access. A similar situation is expected to exist for clean cooking with 910 million remaining without access in 2030; the only continent that is forecasted to not achieve net gains in energy access. This makes the continent an important energy poverty problem and the international community has begun responding to the scale of the issue with a range of initiatives to galvanise, funding, innovation and knowledge generation (REN21 2017).

Acknowledging that one type of solution will not fit all, the expectation is that with increasing involvement of multiple actors across diverse scales and sectors, the necessary conditions for appropriate sustainable and scalable interventions can be achieved (Sovacool 2014*a*). But the global community still lack consensus on what should form guiding principles. The universal target-driven practitioners stress the importance of conditions to support the effective marketing of innovative decentralized energy solutions (Hogarth & Granoff 2015, Practical Action 2016, Desjardins et al. 2014), that are efficient enough to facilitate affordability to the poor (World Bank 2015*a*). Critics of this approach lament what they deem to be solutions that fail to address energy poverty in a meaningful way (Bazilian & Pielke Jr. 2013). Indeed, households tend to engage in the concurrent use of modern energy and traditional energy for the same service (e.g. cooking); in what is known as energy stacking (Berrueta et al. 2008, Guta 2014, Komatsu, Kaneko & Ghosh 2011, Baiyegunhi & Hassan 2014). This challenges the long term effectiveness of attempts to provide universal access to modern energy services. Given a differential as high as a \$48.5 billion in annual financing requirements for universal energy access till 2030 depending on the level of ambition in defining energy access (World Bank 2017*a*), there is a need to clarify what it takes to solve energy poverty in a way that achieves long term welfare and development.

## **1.2 Energy transitions of the energy poor: Lagos, Nigeria**

With the understanding that the energy poor engage with modern energy in varied, complex and changing ways over time, this thesis approaches the energy access issue from the view of household energy service interactions. More specifically the core research undertaken is framed around concepts of household energy transitions in developing countries, which broadly consider the influence of the personal and external environments in which households make decisions over time (Howells et al. 2010, Kowsari & Zerriffi 2011). This framing of the thesis around the behaviour of energy poor households paves the way for the research

to be grounded in methods from the social sciences; for which there have been no shortage of calls from academics and practitioners alike, for further research (see Sovacool 2014*b*). This research also explores the usefulness to policy decision-making of closer alignment between models of developing country household energy demand and the contextual realities of household energy behaviour in these regions.

The strategy adopted in this research emerges from a number of key elements relating to knowledge gaps identified in the literature and relevant regions of exploration in regard to the research objectives and practical undertaking. Some gaps identified in the literature include:

- the current emphasis on the energy resources, systems, and technologies, which has led to fragmented approaches to research and projects with regards to household energy services (e.g. solar home systems for electricity activities, separate from clean cookstoves for cooking activities), even in instances when user perspectives have been given importance. There is a need for more research that provides evidence from a more holistic view of the household-energy interaction, which can capture potential trade-offs and synergies between services and the fuel-technology combinations used to fulfil them.
- A dearth of qualitative case study research in the field situated outside the confines of ongoing/post-project evaluations in the short term. The merits of lessons learned from energy access projects need more support from insights examining the longer-term course of change that have led to sustainability or otherwise, in the existing energy services of the energy poor (traditional or modern).

Household energy behaviours are shaped by interactions at multiple scales of society (including the personal, household, community, region and nation state); an examination of which is usefully tackled by employing case study research. In doing this, the research responds to the critical focus that needs to be given to the SSA region by selecting a case from Nigeria, whose energy access deficit ranks second globally for electricity, and third for clean cooking (World Bank 2017*a*); and which has a long history of issues with its energy market amidst a rapidly growing population (IISD 2012, World Bank 2016*b*). The country's commercial capital Lagos presents an interesting case for researching the energy behaviour of the energy poor, given the diverse nature of energy poverty existing not just within its borders but also between various communities of its rural areas. There is also more data available for Lagos than for other regions of the country, thus opening the methodological opportunities by which knowledge can be generated. The research adopted a pragmatic methodology that involved: fieldwork undertaken in a contextually intriguing case of communities in rural Lagos with little-to-no experience of dedicated energy access

projects/programmes; and modelled exploration of future household energy behaviour in the state.

### 1.3 Research questions and objectives

As stated in Section 1.1, the aim of this thesis is to investigate how the global energy poor can sustainably transition from traditional energy services to modern energy services. Tackling the gaps highlighted in Section 1.2, the above aim is addressed by answering the following research questions:

1. What explanation can be given for the energy behaviour of the energy poor, and thus, the nature of their transition to modern energy services?
2. What do the lived realities of households in rural Lagos reveal about the energy decision-making of the energy poor, and the drivers of sustained behaviour change?
3. How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways for the drivers observed, and what can this inform about facilitating the transition to modern energy services?

From answering these questions, this research provides original contribution to knowledge in the field of energy access by:

- Postulating a concept for understanding the nature of household transition to modern energy services (Chapter 4).
- Using an original case study on rural Lagos to provide empirical evidence on the decision-making of the energy poor and drivers of their sustained engagement with energy services (Chapter 7).
- Developing an innovative energy demand model to explore future energy transitions of Lagos state's households; a model that accounts for features affecting the energy behaviour of the energy poor that are seldom considered in conventional modelling techniques (Chapter 8).

### 1.4 Thesis Structure

The remainder of this thesis is structured as follows: Chapter 2 provides clarity on what is meant by some key terms in the field of energy access; *energy poor* (or *energy poverty*), *energy access*, and *sustainable energy*. In this thesis, the term *energy poverty* refers to the 1.06 billion people without access to electricity globally, and the 3.04 billion people relying on traditional use of solid fuels for their cooking needs; issues largely considered to be developing country concerns. *Energy access* refers to the provision of modern (e.g.

electricity) and/or efficient forms of energy (e.g. improved biomass cook-stoves) to the energy poor. While *sustainable* denotes the sustained use of modern energy. The use of these terms, both academically and in practice varies widely, and differences in their interpretation have major implications on, inter alia, the perception of the energy poverty problem and the prescriptions to address it; particularly during this period of multiple, and potentially competing, global energy for sustainable development issues.

Chapter 3 critically reviews perceptions in the field on what is required for sustainable energy access and explores areas of ongoing debate. Empirical experiences from the 50 years of energy access research, projects and programmes have brought a range of lessons, but also unsolved issues that are broadly structured around three themes: (i) the types of energy services that should be the focus of energy poverty/access activities; (ii) the development of a sustainable market for serving the energy poor; and (iii) the universal desire for modern forms of energy. Realities around the nature in which the energy poor engage with modern forms of energy suggest the need for thinking in terms of *transitions*, in order to generate further knowledge by which ongoing debates can be informed.

In Chapter 4, a conceptual framework is developed to postulate the nature of the energy poor's transition to modern energy services. It illustrates the sustainability of household energy transitions in a way that gives explanation to the different kinds of transitions (e.g. energy stacking), by unpacking the energy-social interaction and linking it with concepts of household energy decision-making, consumer demand, and sustainable livelihoods to describe energy demand. It is put forward, that if the energy poor can undergo changes in the organisation of their daily lives, such that the means by which they could consume modern energy became urgent, as was the urgency of discontinuing the means by which they consumed traditional forms of energy, then traditional energy services can sustainably be substituted by modern energy services.

Chapter 5 describes the methodology adopted to address research questions 2 and 3. For research question 2, it focuses on the process by which field visits produced empirical insights on household energy service decision-making and transitions in five diverse communities of the Epe local government area (LGA) of Lagos state; this forms the basis of discussions had in Chapter 7. The case setting is introduced, and the work undertaken in the field over a total of six months, conducted in two stages is described to illustrate how insights were elicited and verified. Critical attention is given to some of the methodological, practical, and analytical considerations necessary during cross-cultural social science research. For research question 3, the chapter reviews representations of household energy demand in developing country contexts to highlight some of the shortcomings of current approaches, particularly in the inability to capture important aspects of these contexts. It then introduces the scenario analysis adopted to answer research question 3, and discusses some of the innovative features

of the purpose-built Lagos-LEAP household energy demand model.

In Chapter 6, the context of the selected case at the national, state, and local level is presented in detail as it pertains to Nigeria, Lagos, and Epe. To investigate household energy practices at the local level, an appreciation of the forces that have contributed to them is necessary, drawing from an extensive review of a wide range of documents and stakeholder consultations. Nigeria's post-independence history is reviewed to present the backdrop that has led to a troubled energy sector and the characteristics of its unique society. The external drivers that influence household energy decision-making in the country and state — including history, geographical location, ecology, government policies, technological markets, labour markets, capital markets, consumer goods market, security markets, social environment — are reviewed for a rich description of the context at those scales. Attention is then given to life in rural Lagos, with rich descriptions of the social, cultural, economic, and energy developments in the five communities included for fieldwork.

Chapter 7 answers research question 2 by presenting the voices of local residents on their lived experiences to shed light on the interactions that shape their energy decision-making, and drivers behind the transitions they have experienced. These insights were examined in view of the framework developed in Chapter 4. Insights point to some important lessons on how strategies around energy access should be considered, and the position it should be given by governments in energy sector and national development planning.

Chapter 8 details the structure of the Lagos-LEAP model used to explore the household energy demand pathways in Lagos between 2010 and 2043. The pathways are based on narratives of four scenarios describing future developments in the external environment of Lagos' households that lead to varied transitions in the makeup of energy demand. In providing lessons for Nigeria and the international community, results show the forms of modern energy that are most efficient at facilitating the transition away from traditional energy services in Lagos. Results also show how energy stacking can negatively impact policy effectiveness.

Chapter 9 synthesises the research findings; highlighting the main contributions of this research to the field of energy access, and suggesting avenues for future work. It presents a recommendation on the direction needed to address global energy poverty.





## Chapter 2

### SE4ALL: Some Definitions

*Is there clarity on who the global energy poor are, and  
what the goal is?*

## 2.1 Introduction

This chapter presents some of the terms often used in the context of energy poverty and the discrepancies that exist across the literature. Practitioners and researchers have thus far found it challenging to achieve consensus on the definition of energy poverty, and its related terms. Yet consistency in terminology and appropriate definitions are necessary for providing a platform for the international community to measure the state of energy poverty, measure progress, target populations, and prescribe solutions, among others.

Sections 2.2 to 2.4 briefly discuss the terms; *energy poverty*, *energy access*, and *sustainable energy access* respectively, and variances in how they are used. These differences set the scene for some of the ongoing debates reviewed in Chapter 3. Importantly, each section clarifies how the above terms are considered during discussions had in this thesis, before Section 2.5 concludes the chapter.

## 2.2 Energy poverty

The energy dimension of poverty is particularly challenging when attempting to standardise the concept, due to the context-specific realities of the demand for energy. Different physical environments globally, for example, drive critical household needs for energy and thus determine what is considered to be an unacceptable lack of energy.

The foremost irregularity in the understanding of what it means to be energy poor can be found between the *developing* and *developed* world, where disparity exists both semantically and in the essence of definitions. In most developed country contexts the term *fuel poverty* is used to denote a household being energy poor; a term that emerged in the 1970s as energy affordability became a serious political issue in some countries (Li et al. 2014). On the other hand the concept of being energy poor, in terms of developing countries, was initially debated amongst a niche set of researchers following government and donor experiences in bringing cleaner and more efficient (modern) energy to unserved populations in these areas, that saw the emergence of the term *energy poverty* (Halff et al. 2014, World Bank 1996). This is worth clarifying, as there are a few instances where the terms are used interchangeably.

More importantly, the plethora of fuel poverty (hereinafter referred to as energy poverty) definitions across European and other Western nations are largely concerned with heating needs (European Commission 2015, Day et al. 2016, Rademaekers et al. 2016), whereas research and activities in the developing countries focus primarily on cooking and lighting demands. The result has been two areas of work that have progressed independently of each other, with limited attempts to bridge the gap (Bouzarovski & Petrova 2015). In the developing world there is a dearth of what is considered to be modern forms of energy infrastructure to consumptive and productive uses, energy that was considered necessary to meet

the former Millennium Development Goals (MDGs) — therefore definitions and attempts to alleviate these poverty dimensions emerged concerning ways to provide such infrastructure that will facilitate achievement of the MDGs. Whereas in industrialised countries — where there is greater access to and supply of electricity — the focus is on the ability to engage with the energy expenditures required to obtain safe living conditions. In the colder climate of the northern hemisphere where a large number of developed countries reside, it is understandable why heating needs of a household which represent a large percentage of demand, would be the focus of definitions.

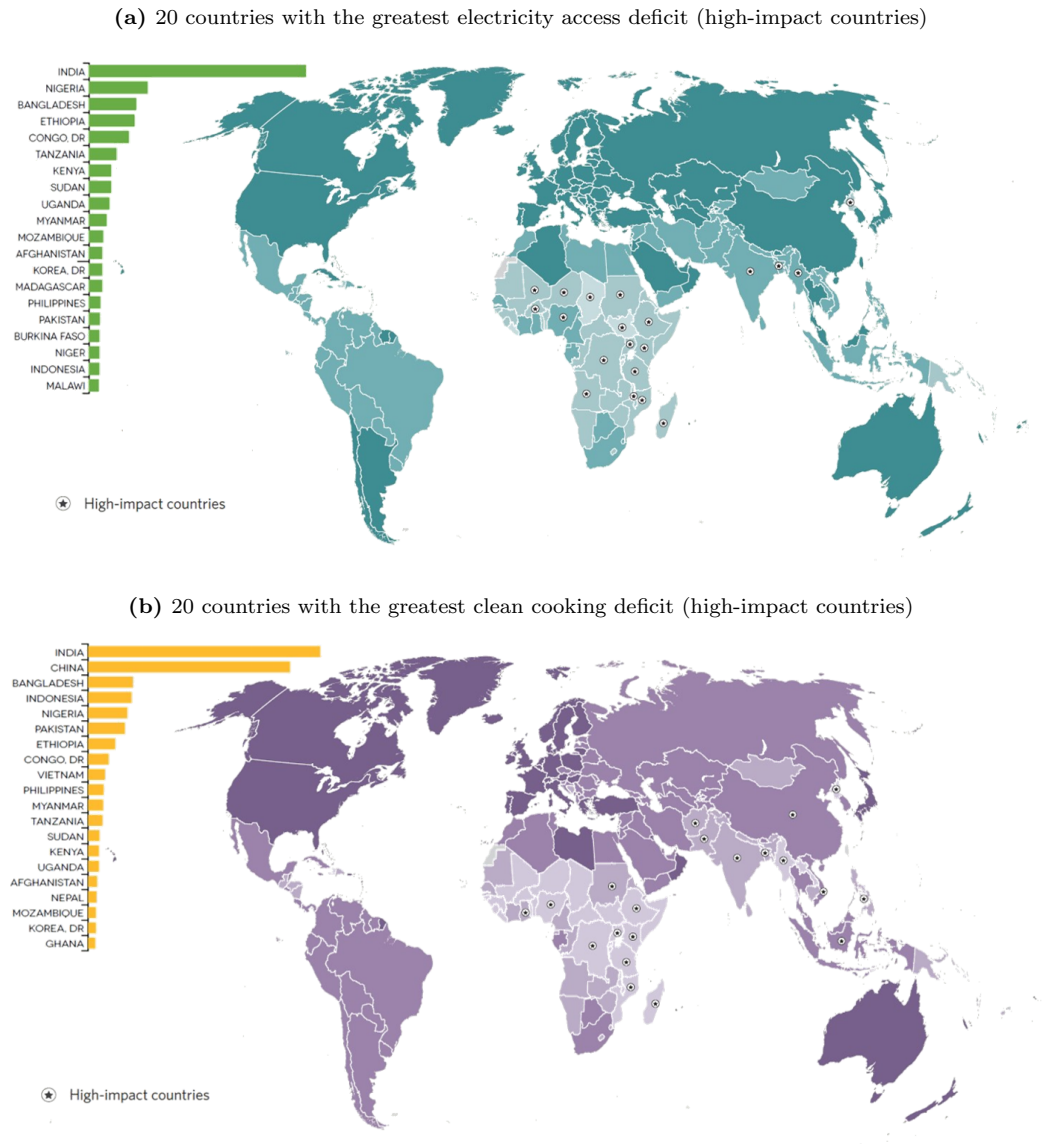
Though there have been some calls to bridge the gap between developed and developing country energy/fuel poverty problems (Day et al. 2016), this research maintains a distinction between the two areas of work. It therefore investigates energy poverty as it relates to the billions of people, typically in developing countries and emerging economies of the Global South, that do not have access to the energy services required to bring them out of poverty (see Figure 2.1). Here, the issues of the energy poor denote not just a problem of ‘affordability’ — as is typically the case in developed world concerns — but also that of ‘availability’.

A distinction is typically made between *modern* energy services and *traditional* energy services; where the former facilitates socio-economic development, well-being and quality of life (alleviating poverty), whereas the latter restricts productivity and poses major health risks (entrenching poverty) (Pachauri & Spreng 2003, Day et al. 2016).<sup>1</sup> It is useful to consider energy poverty from the point of view of final energy rendered to the user, as opposed to the fuel being used, since some fuels can serve to entrench or alleviate poverty depending on the nature of their production and technical characteristics. Thus, biomass burned with an inefficient open (three-stone) stove will be considered traditional cooking in this research. While biomass burned with an efficient or low polluting stove will be considered modern cooking. The literature also sometimes attributes some fuel–technology combinations to be transitional, on the pathway from traditional to modern (e.g. kerosene stove cooking) (Heltberg 2004). Where this tertiary state is used to classify an energy service in this research will be clearly indicated (e.g. in Chapter 7), but in accordance with distinctions typically made in the literature, discussions will predominantly rest around the

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<sup>1</sup>The term ‘energy service’ denotes the process of using a technology to convert a primary/secondary energy resource (fuel) into useful activity (e.g. cooking). The use of the terms ‘traditional energy service’ and ‘modern energy service’ in this work, respectively refer to the use of traditional or modern fuel–technology combinations to achieve a given energy service. For example: biomass burned inefficiently with an open-fire cookstove for cooking to denote traditional energy service; and liquefied petroleum gas (LPG) with an efficient burner for cooking to denote modern energy service. Some energy services can be served by both traditional and modern forms of energy (e.g. cooking and lighting). Other energy services can only be served by modern fuel–technology combinations (e.g. mobile phone charging).

**Figure 2.1:** Energy poor regions of the globe



Source: Adapted from Banerjee et al. (2013) and World Bank (2017a)

Note: Lighter colours indicate lower percentage household access, darker colours indicate higher percentage household access.

traditional and modern distinction.<sup>2</sup> But as Chapters 6 and 7 will show, the distinctions made by practitioners and researchers do not necessarily coincide with distinctions made by local end-users.

If the goal is to “ensure universal access”, then energy poverty can simply be defined as having a “lack of access”. Indeed, this is typically how practitioners and researchers

<sup>2</sup>Such is the importance of going beyond fuels when categorising energy poverty in that though on the one hand kerosene used with a cookstove for cooking can be classified a transitional fuel, it is strongly considered an energy poverty fuel when it used for lighting with a local kerosene lantern, due to *user-perceptions* of the health and safety risks it poses (see Mills 2016).

approach the situation, with definitions such as:

“the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development” (Reddy 2000, p. 44)

“being deprived of certain energy services that fulfil basic human needs in a healthy, convenient, and efficient manner” (Bhatia & Angelou 2014, p. 1)

“the point at which...people are not using enough energy to sustain normal lives” (Barnes et al. 2011, p. 894)

“lack of access to modern forms of energy” (Modi et al. 2006, p. 9)

“inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household and productive activities at sunset” (Gaye 2007, p. 4)

But there are two ways the energy component of energy poverty can be, and has been, considered. First, *a lack of* access to modern energy services as the definitions above illustrate, but also *a reliance* on traditional energy services, as some definitions account for — particularly in the case of cooking energy services:

“negative health outcomes faced mostly by women and children in settings where households rely on solid fuels” (EkouevI & Tuntivate 2011, p. vi)

“The link between energy and poverty is demonstrated by the fact that the poor in developing countries constitute the bulk of an estimated 2.7 billion people relying on traditional biomass for cooking and the overwhelming majority of the 1.4 billion without access to grid electricity” (GEA 2012, p. 153)

Acknowledging the energy poverty concerns associated with both ways of viewing the issue is important because — as a review of the literature in Chapter 3 will show — addressing the absence of modern energy services does not automatically equate to non-reliance on traditional energy service. Thus, can a household be said to be out of energy poverty if they have access to modern cooking, but maintain a reliance on traditional cooking?

## 2.3 Energy access

In the past, a household could be deemed to have achieved energy access at the onset of being connected to an electricity source and ownership of a clean cookstove (Bhatia & Angelou 2015). The importance of considering energy access from the perspective of services rendered to a household necessitated a more nuanced approach to categorising access. How much electricity is being consumed following a connection, how secure is the ability for a household

to make their energy payments over time, are just a couple from many considerations to be had, which also shine a spotlight on the dynamism of energy poverty — as it relates, for example, to urban energy poverty in some countries, despite the presence of grid electricity infrastructure (Sovacool 2014a). Definitions now seek to include criteria that account the extent of provision and continuity of use:

“relating both to physical proximity to energy infrastructure and to the policies and frameworks supporting the transition to better, reliable, and more efficient use of electricity and modern fuels.” (Barnes et al. 2010, p. 1)

“having a connection to adequate, clean, convenient and reliable sources of electricity, household fuels (notably for cooking) and mechanical power for productive uses.” (UNDP 2012, p. 12)

SDG7, similarly defines energy access as “access to affordable, reliable and modern energy services”. The insertion of the words ‘affordable’, ‘reliable’, ‘convenient’, ‘adequate’, and ‘proximity’ in the above definitions, all seek to describe a form of *access* that is usable at the time of need. As alluded to in Section 2.2, these *access* indicators will broadly be categorised into two areas in this work: (i) availability; and (ii) affordability. If an energy service (fuel and conversion technology combination) can be convenient to engage with or be in feasibly close proximity, it means it is suitably available; if it is reliable, then it is available for use when needed; and if it is adequate, then the desired amount has been made available to the consumer. Therefore, energy availability does *not* simply denote the presence of energy infrastructure. For the second category, an available energy service cannot be accessed unless it can be afforded. The words ‘clean’, ‘more efficient’, ‘modern’ and ‘better’ describe the form of *energy* (service) that would be appropriate, such as those touched on in Section 2.2 and later in this section (e.g. efficiently burned biomass, solar-powered electricity, liquefied petroleum gas (LPG), etc.).

Despite greater rigour in definitions, providing a mechanism by which the energy access (or poverty) can be operationalised and measured remains a work in progress. Tools have moved from the single-indicator threshold consumption levels of energy (Barnes et al. 2011), to multidimensional composite indices, such as Practical Action’s energy access index (see Practical Action 2010) and the UN’s multidimensional energy poverty index (see Nussbaumer et al. 2011). The World Bank’s multi-tier framework is setting the global standard for measuring energy access in the bid to track the progress of the energy poverty target of SDG7, and will serve as the reference point for tiers of energy access during discussions in this thesis. The framework breaks down the characteristics of an energy service and its access to distinguish hierarchical tiers of energy access (Bhatia & Angelou 2015). Tables 2.1 to 2.5 illustrate the matrices used to measure access for three areas that are of interest to

this research, out of a total of eight matrices that have been developed for the framework across the household, productive, and community activities.

While the tools for measuring energy access have become more comprehensive, there remains no agreement on what tiers of energy access will bring about poverty alleviation. One example that illustrates the significance of reaching consensus on the issue is the fact that, different tiers of energy access also bring forth considerable differences in the level of financing required to achieve the global goal (this is discussed further in Chapter 3).

Many studies give exclusive attention to a particular energy service, fuel, or fuel-technology combination; be it electricity, or electricity for lighting only, or to productive uses only, or clean cookstoves. This thesis considers a household's access as it pertains to all home-based energy services. While household energy access is the focus of this research, it is nevertheless important to consider energy for productive and community uses, as well as systems of energy produced and delivered at multiple scales (i.e. grid, mini-grid, standalone). Not only because they impact the livelihood of households and their ability to engage in household energy use (Bailis et al. 2009), but also because many households in the context engage in self-employment.<sup>3</sup> Thus, depending on the nature of their work, energy demanded for home purposes are not mutually exclusive from energy demanded for productive uses.

It should be noted that the distinction between energy for basic needs and productive needs “is by no means clear cut” (GEA 2012, p. 1422). For example, Figure 2.2 bundles the provision of electricity to support health care services and education under basic needs, but in many cases, this is not the minimum level of electricity provided under a project/programme, or promoted as a market opportunity. Rather, portable lanterns and improved cookstoves regularly denote the minimum threshold for providing a household with modern energy services. These technologies provide health and educational benefits in the form of reduced exposure to indoor air pollution and opportunity for children to study at night, but *not* energy services for clinic and school activities (Simon et al. 2014, Rahman & Ahmad 2013). On the other hand, the energy services required for clinics to adequately provide health services, or for schools to enhance learning platforms, are often considered productive uses of energy (Cabral et al. 2005, Kaygusuz 2007). Similarly, the provision of small-scale lighting services that extend the business hours of a micro-vendor home-business represent value added through increased income-generating opportunities and therefore can be categorised as the use of energy for productive purposes (Laufer & Schäfer 2011).

Therefore, in this research the distinction between basic and productive energy services is made on the basis of useful outcome. Where in the former (basic use), energy is used for consumptive purposes only; that is, energy consumption that adds no direct value to

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<sup>3</sup>Developing countries are characterised by high informality and self-employment; where households living in rural areas often engage in generational small-holder farming (Gindling & Newhouse 2014).

**Table 2.1:** Multi-tier Matrix for Measuring Access to Cooking Solutions

		LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	
ATTRIBUTES	1. Indoor Air Quality	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	[To be specified by a competent agency, such as WHO, based on health risks]	[To be specified by a competent agency, such as WHO, based on health risks]	[To be specified by a competent agency, such as WHO, based on health risks]	< 35 (WHO IT-1)	< 10 (WHO guideline)	
		CO (mg/m <sup>3</sup> )				< 7 (WHO guideline)		
	2. Cookstove Efficiency  (not to be applied if cooking solution is also used for space heating)		Primary solution meets Tier 1 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 2 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 3 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 4 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]		
	3. Convenience:  Fuel acquisition and preparation time (hrs/week)  Stove preparation time (min/meal)				< 7  < 15	< 3  < 10	< 1.5  < 5	< 0.5  < 2
	4. Safety of Primary Cookstove	IWA safety tiers	Primary solution meets (provisional) IWA Tier 1 for Safety	Primary solution meets (provisional) IWA Tier 2	Primary solution meets (provisional) IWA Tier 3	Primary solution meets (provisional) IWA Tier 4		
		OR Past accidents (burns and unintended fires)					No accidents over the past year that required professional medical attention	
	5. Affordability						Levelized cost of cooking solution (inc. cookstove and fuel) < 5% of household income	
	6. Quality of Primary Fuel: variations in heat rate due to fuel quality that affects ease of cooking						No major effect	
	7. Availability of Primary Fuel						Primary fuel is readily available for at least 80% of the year	Primary fuel is readily available throughout the year

Source: Bhatia & Angelou (2015)



**Table 2.2:** Multi-tier Matrix for Measuring Access to Household Electricity Supply

			TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
ATTRIBUTES	1. Peak Capacity	Power capacity ratings <sup>28</sup> (in W or daily Wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
				Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		OR Services		Lighting of 1,000 lmhr/day	Electrical lighting, air circulation, television, and phone charging are possible			
	2. Availability (Duration)	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
		Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
	3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
	4. Quality						Voltage problems do not affect the use of desired appliances	
	5. Affordability					Cost of a standard consumption package of 365 kWh/year < 5% of household income		
	6. Legality						Bill is paid to the utility, pre-paid card seller, or authorized representative	
	7. Health & Safety						Absence of past accidents and perception of high risk in the future	

Source: Bhatia & Angelou (2015)

**Table 2.3:** Multi-tier Matrix for Measuring Access to Household Electricity Service

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Tier criteria		Task lighting AND Phone charging	General lighting AND Phone Charging AND Television AND Fan (if needed)	Tier 2 AND Any medium-power appliances	Tier 3 AND Any high-power appliances	Tier 2 AND Any very high-power appliances

Source: Bhatia & Angelou (2015)

**Table 2.4:** Multi-tier Matrix for Measuring Access to Household Electricity Consumption

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Annual consumption levels, in kWhs		≥4.5	≥73	≥365	≥1,250	≥3,000
Daily consumption levels, in Whs		≥12	≥200	≥1,000	≥3,425	≥8,219

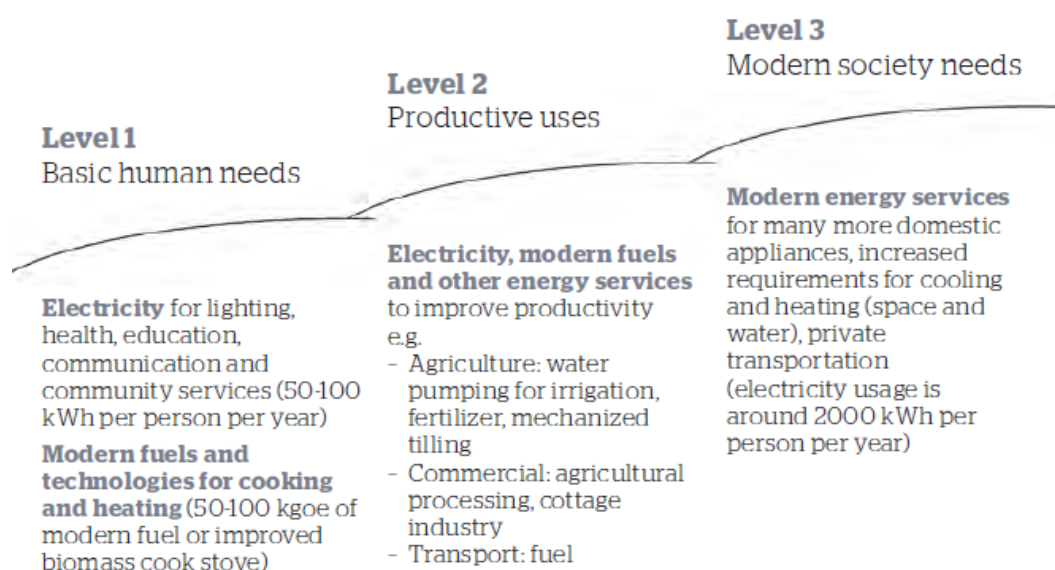
Source: Bhatia & Angelou (2015)

**Table 2.5:** Multi-tier Matrix for Measuring Access to Street Lighting

STREET LIGHTING		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
ATTRIBUTES	1. Capacity		At least one functional street lamp in the neighborhood	At least 25% of the neighborhood is covered by functional street lamps	At least 50% of the neighborhood is covered by functional street lamps	At least 75% of the neighborhood is covered by functional street lamps	At least 95% of the neighborhood is covered by functional street lamps
	2. Availability (duration)		Street lighting functions for at least 2 night hours each day	Street lighting functions for at least 4 night hours each day	Street lighting functions for at least 50% of night hours each day	Street lighting functions for at least 75% of night hours each day	Street lighting functions for at least 95% of night hours each day
	3. Reliability					No reliability issues perceived by users	
	4. Quality					No brightness issues perceived by users	
	5. Safety					No perceived risk of electrocution due to poor installation or maintenance	

Source: Bhatia & Angelou (2015)

**Figure 2.2:** An illustration of the various services for energy access



Source: AGECC (2010)

the assets of a household (i.e. energy for home-lighting, mobile phone charging, home-cooking, television, radio, and other consumptive demands). While the latter (productive use) denotes energy for services that directly contribute to household or enterprise income generation, or supports functional operation of public services (such as refrigeration for vaccine storage and lighting in treatment rooms, as well as public lighting).

## 2.4 Sustainable energy access

The final area of consideration is the notion of *sustainability*. Though the word does not feature in the phrasing of the energy poverty target of SDG7, it is at the forefront of the agenda upon which SDG7 is founded: Sustainable Energy for All (SE4ALL). The term ‘sustainable’ has been used for different purposes in the literature with respect to energy access, making it necessary to clarify these positions and how the term will be used in this work. The term has typically been used in two distinct but connected ways: (i) to categorise energy services whose systems of production and consumption do not threaten planetary boundaries; and (ii) to denote the continuity of access to modern energy services for a consumer.

Universally, the term ‘sustainability’ is concerned with the impacts human activity is having on humans and the planet, and the importance of marrying the issues of development and the environment, as afforded by the classic definition of sustainable development: “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). This is the first area of application, which seeks to achieve cleaner energy services in energy poor regions of the globe. Ensuring developmentally-adequate supply and consumption of energy is of importance to the above concerns, but not the central focus (Mainali et al. 2014, Xiaohua & Zhenmin 2002, Iliskog 2008, Oyedepo 2014). In the second area of application, because energy access involves the provision and consumption of energy and/or services not previously accessible, sustainability also refers to the continuity of supply and use of newly accessible energy services (Pachauri 2011, Chaurey 2004).

Interestingly, the above two desires are somewhat mutually dependent. For modern energy supply to be consistently supplied and used, the fuel resources to do so must be available in the long term, and need to be harvested or harnessed in a manner that does not erroneously impact local sovereignty and ecosystems (Laldjebaev et al. 2016). The consistency of supply of an energy service and its impact on the environment, both have major consequences on human livelihoods and the ability for a person/household to sustain their livelihoods — this has a further dimension of therefore impacting the consistency of consumption (Cherni & Hill 2009, Wakeford et al. 2015, Brent & Kruger 2009). Thus, it is expedient for energy access practitioners to address both areas of sustainability in

parallel. However, conflict between the two views of sustainability can arise when navigating preferences such as the speed of results and the ease/difficulty of achieving them (e.g. costs) (see Fuso Nerini et al. 2015); for instance, in cases where the energy forms that can be quickly accessed and easily sustained to achieve the goal of poverty alleviation in a given region over the short to medium term are appealing, though they have systems of production and consumption that are harmful to the planet in the medium to long term.

Since the focus of this thesis is on household energy *transitions*, which require examinations of change over time, the dominant use of the term ‘sustainable’ will be to denote continuity of access. The thesis acknowledges the socially and environmentally sound characteristics of energy with the term ‘modern’. Household energy transitions will be the subject of Chapter 4 where further clarification on the use of the term ‘transition’ will be given.

## 2.5 Conclusion

There are different ways in which energy poverty and its related terms can be viewed and defined. Critically, though we know the goal is to provide all peoples with access to affordable, reliable and modern energy services, there are no clear indicators by which access can be said to have been achieved in a manner that alleviates poverty. The use of the terms energy poverty, energy access, and sustainability in this work have been clarified. Energy poverty denotes primary reliance on traditional fuel–technology combinations to undertake an energy service rather than the alternative modern forms, and an inability to use other welfare–improving energy services. Energy access is concerned with the availability and affordability of the range of modern energy services provided and demanded for household activities, where the multi-tier framework will facilitate broad attribution of tiers of access. And finally, sustainability will concern itself predominantly with the ability for energy access to be sustained over time. The next chapter will review the literature in the field of household energy poverty/access to identify gaps in our understanding on the issue of energy poverty and achieving the goal of *sustainable energy access*. The research questions addressed in this thesis emerge from this review.

## Chapter 3

# Perceptions of How to Achieve Universal Energy Access

*In view of the household-energy interaction, what is the state of knowledge on how to achieve universal energy access, and where are some of the knowledge gaps?*

### 3.1 Introduction

After clarifying some of the key words that will be used during discussions in this thesis in Chapter 2, this chapter presents some elements of the state of knowledge in the field of energy access. It critically reviews perceptions in the literature on what is required for sustainable energy access and explores areas of ongoing debate. The chapter is structured around key areas of discussion that have emerged from decades of growing research, projects/programmes, lessons learned, and unsolved issues. Academic literature is the main domain used to explore the frontier of knowledge in the field, but given the active role of multilateral institutions, development institutions, NGOs, commercial practitioners, and other knowledge networks in the field, these resources also form an invaluable source of literature. Insights from relatively successful energy access experiences at the national level are presented as a follow-up to debates reviewed. The review of some of the English-speaking literature will converge on the energy behaviour of the energy poor, which forms the focus of this research, revealing some of the gaps in our knowledge and areas of methodological exploration to generate new knowledge that can inform debates explored throughout the review.

The rest of the chapter is structured as follows: Section 3.2 will provide a brief history of the energy access field, categorising three themes of energy access debate that have been difficult to resolve and/or require further understanding. Sections 3.3 to 3.5 will critically review the debates around these three themes. Section 3.6 spells out the research questions answered in this thesis and the methodological observations in the literature that informed them, before Section 3.7 concludes the chapter.

### 3.2 Lessons from historical experiences

The adoption of universal energy access as part of a global Sustainable Development Goal shines a spotlight on 50 years of practice and research on delivering modern energy services in developing countries. This experience — from the early efforts of donors and national governments, to more recent multi-stakeholder involvement including the private sector — has led to a number of basic agreements on what works and what does not work. Most notable of those that have been addressed include the understanding that:

- the provision of free technology is unsustainable, and projects must be scrutinised according to appropriate technical, social and economic criteria.
- the simple provision of technically superior technologies is insufficient for local needs.
- donor leadership alone, of projects, is insufficient.

These are briefly expanded on below, before outlining other issues that have been acknowledged by the international community, but have proved difficult to address and split expert opinion on the solutions required.

### ***Investment case should be on appropriate technical and economic criteria***

The energy poor can largely be found in rural regions of developing countries where conditions do not favour energy infrastructure investments: populations are dispersed; there exist low levels of energy consumption, highly concentrated in peak periods; incomes are seasonal; and physical access tends to be challenging (Haanyika 2006, IEG 2008). As a result, early activities by donors were justified not on commercial grounds, but on the anticipated social and economic benefits to local people (World Bank 1975, Foley 1992*a*). Such benefits included: the stimulation of rural development, mitigation of rural–urban migration, and improving the livelihoods of the poor (Ross 1972, Barnes 1988). On this basis were investments in centralized grid extension undertaken in the 1960s and 70s, which proved to have minimal impact on the above benefits (IEG 2008, Barnes 1988).

In the 1980s, after isolated communities were deemed unsuitable for grid infrastructure investments, small-scale renewable energy technologies were disseminated to the energy poor with heavy subsidies (as high as 90 %), or for free, as part of donor projects (ESMAP 2000, Kozloff & Shobowale 1994). Again, the benefits of these activities could not justify the cost of installing systems that quickly went out of use due to maintenance difficulties (Martinot et al. 2002, Foley 1992*a*). Numerous reviews and post-project evaluations by researchers and donors, were strong in emphasising the importance of a commercially sustainable approach to energy access (Pearce & Webb 1987, Martinot et al. 2002, Kozloff & Shobowale 1994, Foley 1992*a,b*, Halpern & Barnes 2001, IEG 2008).

### ***Technically superior technologies are not all that matter***

Early experience with efficient cookstove dissemination is an example of the activities which showed that local users needed more than just technically-superior energy technologies. Eckholm’s (1975) publication on the effects of rural cooking and heating practices in the developing world on deforestation, intensified the activities of bilateral and multilateral development institutions to improve the efficiency of biomass cookstoves used by the energy poor (Sesan 2014). It was expected that the dissemination of technically superior cooking technologies — whose fuel efficiency would benefit households by lowering their fuel costs or time allocated to fuel collection — would induce demand and become self-sustaining (Crewe 1997). Limited attention to the effects of culture, social norms and insecure circumstances of the energy poor, led to poorly designed cookstoves that brought about many failed projects (Barnes et al. 1994).

### ***Donor leadership alone of projects is insufficient***

Part of the genesis for donor and other non-governmental organisation (NGO) activity in delivering energy access stemmed from the limited capacities of state governments and

the unattractiveness of rural areas to profit-seeking actors (Bacon & Besant-Jones 2001, Haanyika 2006). However, the experiences presented above, and the scale and complexity of energy poverty, suggested that donors cannot alone provide the widespread and self-sustaining interventions energy access requires (Kozloff & Shobowale 1994). It was understood that future projects needed to:

- foster local involvement in energy access projects to ensure solutions are appropriate to the local context (Chambers 1992, Karekezi & Murimi 1995, Ramakrishna 1995, Barnes et al. 1994).
- adopt a commercial approach to energy access whereby donors and governments work to create and demonstrate a market environment in which the private sector can participate in the provision of modern energy services (World Bank 1996, IEG 2008, Martinot et al. 2002).

The international community continues to wrestle with the above two issues, which at times serve to contradict one another (Campbell et al. 2016). Experience with the commercial approach to energy access has also revealed other issues that remain unsolved:

- energy access tends to be context-specific and solutions successful in one case can be unsuccessful in another, due to differences of culture, politics, natural environment, and other market characteristics that can change the outcome of a given solution (policy, technology, etc.) (Sovacool 2014a, Reiche et al. 2006). This has made it difficult to replicate successful projects, and also hampered the ability to increase the scale of impacts and develop the market (Lemaire 2014, Bhattacharyya & Ohiare 2012).
- when the energy poor receive access to modern energy services, the likely outcome has been to combine their use with their pre-existing traditional energy services (i.e. energy stacking — further discussed in Section 3.5) (Berrueta et al. 2008, Baiyegunhi & Hassan 2014, Martinot et al. 2002, IEA 2006). This not only calls into question the effectiveness of energy access in addressing the harmful effects of energy poverty (Andadari et al. 2014, Kebede et al. 2002, Banerjee et al. 2016), but potentially affects the sustainability of modern energy access.
- there is a need to engage multiple stakeholders undertaking various and relevant activities to the effective implementation of projects/programmes (van Gevelt et al. 2016, Sovacool 2014a, Yaqoot et al. 2016, Rehman et al. 2017).



The above lessons are expanded on in the sections that follow. They are the foundation of a number of debates ongoing in the field, as researchers and practitioners seek to better understand and address them. These debates are structured into three themes explored below: (i) the types of energy services that should be the focus of energy poverty activities; (ii) the development of a sustainable market for serving the energy poor; and (iii) the notion that modern energy services are universally desired.

### 3.3 Energy access for basic vs. productive uses

Since the early activities on energy access, there have been debates on what type of projects should constitute the focus of interventions. Uncertainties over the realised social and economic benefits of rural electrification projects and the equity of those benefits divided opinion on the strategies to be adopted. It was argued that poor people were unable to afford electricity provided, which benefited only wealthier households in a rural community. It was therefore proposed to be more beneficial to electrify productive activities to create jobs that raised incomes, and thus affordability (Barnes 1988). At the same time, it was argued that the economic benefits of electricity to enhance the productivity of agriculture and small-scale industries would also be limited to wealthier households, since subsistence farmers lacked the capital to invest in associated technologies (Barnes 2007). It was observed that in successful projects that aimed to provide electricity for productive activities, complementary government policies were present, such as facilitating access to rural markets, access to credit, and the dissemination of agricultural inputs (Bose 1994). Thus, it was also considered that activities should be focussed on rural development, which had a more direct impact on the poor, than rural electrification (Barnes 2007).

In addition, energy access activities were accused of being historically skewed towards electrification activities (Bhattacharyya 2012). In the late 1990s, one scholar labelled clean cooking activities as an “abandoned priority” that suggested an acceptance of the gender bias against poor women (Reddy 1999, p. 3435). This issue has since received growing attention in the decades that have followed.

More recently, the debate challenges the decision to focus on energy for “basic” services versus energy for “productive” services.<sup>1</sup> An indication of the international community’s stance on the issue is the fact that in the period 2000–2008 household-electricity dominated World Bank energy access lending in accordance with the poverty and market focus given to energy access following the 1992 United Nations Conference on Environment and Devel-

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<sup>1</sup>Section 2.3 described what is meant by the terms ‘basic’ and ‘productive’ energy services in this thesis.

opment (Rio Earth summit).<sup>2</sup> However, this has not been without its critics. A number of experts have since highlighted limited impacts on development and a lack of equity in the provision of energy for basic services (Bastakoti 2006, Bhattacharyya 2012, Sovacool et al. 2012, Rahman & Ahmad 2013, Bazilian & Pielke Jr. 2013). Some argue that the anticipated social benefits of basic energy services — such as aiding education — do not materialise (Wamukonya 2007, Stojanovski et al. 2017, Kudo et al. 2017). Yet, others reason as to the appropriateness of small-scale solutions and their observed benefits (Komatsu, Kaneko & Ghosh 2011, Komatsu et al. 2013, Pode 2013, van der Vleuten et al. 2007, Wijayatunga & Attalage 2005).

Supporters of energy access for basic services argue that the energy poor are being forced to rely on expensive and dangerous fuels such as kerosene for poor quality lighting services (Komatsu, Kaneko, Shrestha & Ghosh 2011, Practical Action 2014). They argue that the energy poor are also forced to rely on the use of indoor air-polluting traditional cookstoves, which are the fourth leading cause of death globally (Lim et al. 2012), after having subjected women and children to the arduous task of harvesting and transporting the biomass fuel used in the process; costing them the opportunity to engage in productive activities (GEA 2012). Therefore, any form of energy that relieves them of these lifestyle conditions — such as the provision of solar lanterns to replace kerosene, and the provision of less-polluting cookstoves relying on alternative fuels or sustainably harvested and easily accessible biomass — should be considered suitable to addressing energy poverty.

Critics of the concept of energy for ‘basic’ services argue that advocates of this concept are promoting energy access for services they themselves would consider inadequate to lead a lifestyle acceptable to them; accusing the approach to be “minimalist” (Velumail 2011: cited in Sovacool 2012) and “unacceptably modest” (Bazilian & Pielke Jr. 2013). In their critique of current efforts to provide universal energy access — which they describe as “poverty management” — Bazilian & Pielke Jr. (2013) draw similarities between energy access for basic energy services and the achievement of an income level that corresponds to ‘relative poverty’:<sup>3</sup>

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<sup>2</sup>The Rio Earth Summit put a spotlight on strong links between energy and poverty, and it was the belief that the market-route was the most effective and sustainable way to address the issue. Regarding poverty, in 1996 the World Bank highlighted: “Development practitioners now understand that they should not view the “fuelwood problem” and its resolution in an isolated way, but as part of the larger problem of energy supplies, poverty alleviation, and the protection of natural resources in rural areas.” (World Bank 1996, p. 25). In 2001 the Bank affirmed: “Efficient and clean energy supply is central to the reduction of poverty through many and varied linkages, as well as being important for economic growth” (IEG 2008, p. 55). Regarding the market approach the Bank stated: “Evidence suggests that people will spend a significant proportion of their incomes on better energy, which improves their quality of life or enables them to become more productive” (World Bank 1996, p. 5). Again in 2008, on the benefits from lighting and television services: “people who live in rural areas greatly appreciate these benefits and are willing to pay for them at levels more than sufficient to cover the costs.” (IEG 2008, p. xiii).

<sup>3</sup>The parallel drawn here suggests that if energy poverty can be looked at in the same manner as ‘absolute poverty’ in income terms — both of which the international community desires to take populations out of — then the provision of modern energy for basic services is akin to raising people out of absolute poverty but maintaining them in ‘relative poverty’. Poverty lines used in quote are from 1990, prior to the updated thresholds provided by the World Bank in 2015 (Ferreira et al. 2015).

“Consider that we do not label people who live on more than \$1 per day as having “economic access” and address policies toward achieving a \$1.25 level, thus still leaving them desperately poor. Everyone understands that \$1.25 a day is still not nearly enough. In energy we often lack such conceptual clarity.” (Bazilian & Pielke Jr. 2013, p. 76)

They use this analogy to illustrate that current approaches are insufficient to raise the energy consumption of developing countries — where most of the energy poor resides — to levels commensurate with economic growth and the alleviation of poverty. An indication of their criticism is the fact the majority of energy access activities can be categorised as providing tier 1 and 2 energy services (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016). The differences in the tier-levels of energy access opted for become significant when acknowledging the extent to which they differ in terms of estimated financing required. Universal energy access at tier 1 would require \$1.5 billion annually till 2030, whereas at tier 5 \$50 billion annually will be required (Bhatia & Angelou 2015).

It is useful to bear in mind that the energy poor require access to more, and cleaner energy *services*, not necessarily increased consumption (van der Vleuten et al. 2007). Therefore, if the energy services they require to bring them out of energy poverty can be provided in an energy efficient manner, then this should be the chosen course of action. Nevertheless, Bazilian & Pielke Jr. (2013) are correct in highlighting that countries where the energy poor reside aspire to energy services that will bring about economic growth *and* poverty alleviation, and taking these aspirations seriously will necessitate more than access to energy for basic services. It has been argued that “even in its broadest interpretation, energy poverty does not capture the full extent of human deprivation” (Rao et al. 2014, p. 749). Is it enough then, to address energy poverty with ‘energy access’ — as defined by global institutions or respective national governments (see Section 2.3) — or should the aim be to provide energy access that addresses wider human deprivation, such as the provision of opportunities and raising standards of living?

The above suggests the need to also give energy poverty attention to energy for services that grow a country’s economy. While acknowledging the importance of this, some practitioners — such as the UK’s Overseas Development Institute (ODI) — argue that it is not, and should not be, the energy poverty “priority” (Hogarth & Granoff 2015). According to these authors, investment in centralized electricity generation that would most benefit industry, is unlikely to reach the poor and does not address critical aspects of energy poverty such as cooking practices. The UK-based NGO, Practical Action, also stress the need to focus on smaller-scale energy provision (Practical Action 2016). For these international development practitioners there is an acknowledgement that energy for productive activities

that directly impact the energy poor are necessary, i.e. energy to schools, and health care centres in communities, but they also advocate the importance of modern energy for lighting, cleaner cooking, and other small household appliances. However, in the face of limited financing for energy access projects, household and community energy do not receive equal attention, and experts question what seems to be a focus on the household (see below).

Clean cooking activities are justified by the alleviation of health risks to cookstove users, and the liberation of women and children from arduous and unsafe activities. Healthcare professionals argue, however, that greater attention needs to be given to the health risks faced by the energy poor as a result of poor energy access to healthcare facilities (Franco et al. 2017). In 2013 it was estimated that health facilities serving about 1 billion people globally did not have access to electricity (Practical Action 2013). The oft-cited drawbacks to this include the inability to provide lighting for night-time services, or refrigeration for the storage of vaccines (WHO 2015). Other worrying considerations include the impact of power cuts on some forms of anaesthesia, or during surgery, and the immediate threat that poses to a patient's life (Franco et al. 2017, Klinger et al. 2014). These energy poor conditions further exacerbate the situation as skilled healthcare professionals are deterred from taking up employment in regions that are considered energy poor (Franco et al. 2017, Practical Action 2013).

Energy to power clinical facilities to ensure the safety of a baby and mother in labour would seem just as much an energy access priority as alleviating the health effects of indoor air pollution. Indeed, it can be considered whether lighting for night-time home studying is a more effective and equitable form of energy for education, than electricity at schools being used to integrate children into the IT world of the 21<sup>st</sup> century. Another necessary consideration includes whether or not the protection of women from assault is better achieved by removing their need to walk long distances to collect fuelwood, or by providing street lighting. Both would seem to be of importance as women have been assaulted in daylight (while searching for fuelwood, food or water) and at night (UNIDO 2013). Looking beyond energy and a 'specific' energy technology, as is sometimes the focus of activities, it can also be questioned whether gendered solutions that consider only a woman's health risks from indoor air pollution and not the amount of time she spends collecting firewood, collecting water, preserving food, and manually processing farm produce, can sustainably address *poverty* (Makhabane 2002). It would seem that the key consideration is which of these services can galvanise development in a way that not only addresses the initial provision of energy, but attracts the necessary products, services, and resources that will ensure sustained energy provision to support growth.

### ***Technical solution selection: stand-alone vs. mini-grid vs. grid***

The attributes of energy poor regions are such that, in many cases, the most cost-effective and timely approach to energy access is through decentralized energy technologies/systems (Pode 2013, Hogarth & Granoff 2015, Practical Action 2016). The decision to use grid extension, mini-grids, or stand-alone household systems as a means to provide energy access is dependent on a number of considerations that determine the techno-economic appropriateness of a solution. These include: the population density of a community; its distance to grid infrastructure; average daily energy demand; local access to human and fuel resources; and the terrain (Zeyringer et al. 2015, Mainali & Silveira 2013, Mentis et al. 2015, Palit & Chaurey 2011, Chaurey & Kandpal 2010). Environmental considerations are typically based on the fuel being used, where renewables represent the desired pathway, and this is considered along with necessary costs, resources availability, and technical feasibility on a case by case basis (Mainali & Silveira 2013).

Thresholds for decision-making depend on local realities. Generally, grid extension becomes unfavourable when physical access to a community is challenging, therefore increasing the cost of extending and servicing centralised access; for example, when the community distance from a medium-voltage substation is exceeding 25–30 km (Mentis et al. 2015, Mainali & Silveira 2013). At these distances off-grid systems become cost-competitive and the choice between a mini-grid or stand-alone technology depends on resource availability/potential and load density; one study finding stand-alone technologies to be more suitable when the number of households within a square-kilometre is approximately 10 (Mainali & Silveira 2013).

The above consider the optimal energy system for project *viability* from the perspective of the supplier or the investor, and the environment; being mindful of the expected affordability potential and energy demand of the consumer. However, the service desires of users can be incompatible with the optimal energy system approach of the project implementers, depending on the individual, social, and cultural context. For example, Mainali & Silveira (2015) found that small-scale energy systems such as Solar Home System (SHS) and Wind Home Systems (WHS) in India are less sustainable than larger scale energy systems such as micro and pico-hydro, and biomass-based mini/micro-grids.<sup>4</sup> This was due, in part, to more favourable attributes to users, in terms of energy availability, reliability, and compatibility to different end uses.

Given these realities, in addition to other feasibility considerations, it has been recommended that as opposed to considering grid, mini/micro-grid, and stand-alone energy systems as competing alternatives for energy access, they should be seen as complementary

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<sup>4</sup>SHS, WHS and pico-hydro systems are typically sized <1 kW, but as an example, pico-hydro systems in 2015 India had considerably better conversion efficiencies than the other two (see Mainali & Silveira 2015). Micro/mini-grid systems are upwards of 1 kW in system size.

(Palit & Bandyopadhyay 2016). The idea here is that in areas where service from the grid is not cost-effective, off-grid solutions should be adopted; but planning projects such that as local demand increases and/or grid extension becomes feasible, opportunities for scaling supply or integration with the grid is possible. This idea has been presented as a possible sequencing approach to energy access: where a region initially achieving energy access for “basic” needs through stand-alone technology can progress to the use of energy for “modern living”, as the technologies serve to create a market for mini/micro-grids, which could then be connected to the grid (Bhattacharyya & Palit 2016).

This presents an opportunity with mini/micro-grids if the technical, institutional and policy requirements are in place to facilitate scalable systems or grid-compatible systems to overcome grid encroachment (Lemaire 2011, Williams et al. 2015). However, it is uncertain whether small-scale energy technologies providing limited loads for lighting, cooking and mobile phone services can bring about the local development and increase in local energy demand needed to justify the switch to a mini/micro-grid (Chattopadhyay et al. 2015).

For example, Komatsu, Kaneko & Ghosh (2011) used a survey of SHS and non-SHS users in three rural Bangladesh districts to argue that although the scale of SHS is small, the benefits are substantial.<sup>5</sup> They cite benefits in the form of reduced kerosene costs, and lifestyle benefits through better quality lighting, TV entertainment and information, and in-home mobile phone charging. Rahman & Ahmad (2013) challenged the significance of these impacts after examining the literature on SHS experiences in Bangladesh. They concluded that since there was no evidence of SHS contributing to higher incomes, employment generation, healthcare access, and other human development indicators, then it cannot be said to have any significant impact on rural development. They go further and challenge the claim that SHS improves the education of children through higher quality lighting for night-time studying, arguing that the provision of lighting only provides the *opportunity* for study, but this opportunity can both be used for productive and unproductive activities. Kudo et al. (2017, p. 1) support this claim, as their research in northern Bangladesh found that “improving the home-study environment solely through the provision of solar products may have a limited impact on children’s educational achievement”.

Similar findings have been observed in other contexts. Stojanovski et al. (2017) find that the benefits of SHS in Uganda and Kenya were limited to reducing household kerosene consumption and facilitating in-house mobile phone charging, and other social spillovers. They did not observe evidence to suggest that SHS was used for income generating activities by extending working hours or providing opportunities for new businesses. Interestingly, the recent growth in stand-alone home energy technologies for energy access in Sub-Saharan

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<sup>5</sup>The study sampled users in a market that mainly demanded 40–65 Wp systems, which supported no more than one or two lamps, black and white TV, and mobile phone charging.

Africa (SSA) have largely been based on smaller-scale technologies than ones found in Bangladesh, such as solar lanterns for lighting and mobile phone charging services alone (pico-PV: as low as <10 W and no more than 20 W systems) (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016).<sup>6</sup>

The energy-growth nexus field still lacks “consensus on the effect or direction of causality” between energy consumption and economic growth, with suggestions of bi-directional effects depending on factors considered (Adams et al. 2016, p. 39). How this may manifest itself at the local level between energy access and development has been explained by Lucas (1987) in this way:

“RE [rural electrification] can proceed through anything up to four phases. In the initial phase, electricity is generated privately for large, isolated loads where the productivity of electricity is high. Normally the requirements are for heat, light, power and refrigeration in food processing and agriculture, including irrigation. The prime movers are often diesel engines and occasionally steam turbines, if they can be fuelled by agricultural residues. In a second phase, a collective demand develops for public and private lighting and small farms and businesses. In this phase small networks are often extended from autogenerators installed in the first phase. This is viable because the marginal costs of the extension are low. In the third phase, these micro grids are connected to a major grid, smaller, marginal loads are connected and new processes may appear. Existing prime movers are, sooner or later, substituted by grid supplies and the engines are transferred (by the RE planning department of the utility or the market) to marginal applications elsewhere. In the fourth phase, centres of low demand in the surrounding region can be connected to the grid at low cost.” (ibid., p. 594)

The renewables revolution over the last decade, which have rapidly become cost-competitive in many markets for both centralized and decentralized generation, means that the process described in the quote above can be based on cleaner and local sources of energy (IRENA 2016). But it does describes a potential sequential process from the stage of a *micro/mini-grid*. It would seem that if the systems of energy access cannot facilitate development and societal change that bring about productive demands for energy, then there is a risk of trapping the energy poor “at a subsistence level” of energy access (Lucas 1987, p. 596). Lucas’s (1987) suggestion of using anchor loads as a basis for electrifying a community has been echoed over the years (Terrado et al. 2008, Chaurey et al. 2012, Palit et al. 2014, Ramchandran et al. 2016), and there are very recent examples of private suppliers in countries such as India and Zambia that are adopting this approach to off-grid energy access provision for

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<sup>6</sup>In 2016, 94 % of all off-grid solar products sold were of the pico scale (REN21 2017).

productive activity and household consumption (see IEA 2017).

Nevertheless, the provision of small-scale energy systems are beneficial to the energy poor, and can usefully serve as a pre-electrification option before a higher tier of energy is made accessible (Lysen 2013), just as those connected to grid or mini-grid infrastructure can be subjected to decades of low-tier energy provision due to extended blackout periods — and thus, remain in energy poverty (Sandwell et al. 2016). Section 3.3.1 will briefly review approaches adopted in some successful country experiences.

### 3.3.1 Insights from successful countries

The majority of projects providing the energy poor with stand-alone energy technologies for basic needs tend to be small in scale (number of beneficiaries).<sup>7</sup> Bangladesh’s SHS programme has been the largest energy access programme for systems providing basic needs and its scale falls well short of those found with grid-based energy access projects.<sup>8</sup> Khennas (2012) highlights that this is one of the reasons why stand-alone energy programmes have had only a marginal contribution to energy access efforts: an inability to lower transaction costs through scale economies. Between 1990 and 2010, 70 % of the 1.7 billion people that gained access to electricity were in urban areas (Banerjee et al. 2013); largely served by the grid, with most rural areas also receiving access via extension of the grid. Indeed, countries that have made substantial progress in alleviating electricity poverty over the past 20 years have done so with the use of larger-scale energy systems (Bhattacharyya 2012).

China’s impressive electrification effort that saw household access rate increase from 13 % to 97 % between 1978 and 1997, was achieved largely through grid extension (Peng & Pan 2006, Bhattacharyya & Ohiare 2012); and where off-grid energy systems were utilised, the emphasis was on mini/micro-grids as opposed to stand-alone systems (Han et al. 2014). This presented the opportunity to initially tailor local grids to the limited energy demand found in rural areas, before later integrating it with the central grid system as demand increased over time (Bhattacharyya 2012). In essence, the country adopted the phased development approach described by Lucas (1987) that began with a mini/micro-grid; *not* an individual stand-alone system.

Similarly, the rapid increase in the rate of rural electrification in Morocco from 18 %

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<sup>7</sup>Typical SHS or ICS projects achieve distribution of units in the tens of thousands of units over the lifespan of the project. China’s 2002–2007 SHS project under its Renewable Energy Development Program is on the larger end of the scale, having achieved the distribution of 400,000 units in 5 years (Sovacool 2013b). More recently, commercial off-grid solar technology provider head-quartered in Kenya M-KOPA, has achieved the largest scale of all commercial providers in the market; with 250,000 cumulative sales of mainly pico-PV (solar lantern) products between 2012 and 2015 (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016), and suggested to have reached 600,000 homes as at 2018 (M-KOPA Solar 2018). As at 2016, most other commercial providers in the market achieved cumulative sales in the low tens of thousands (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016).

<sup>8</sup>Bangladesh’s off-grid solar installations soared from 15,475 in 2003, to an impressive 3 million in 2014, but this amounts to only 10 % of the off-grid population (Khandker et al. 2014). Whereas Bangladesh’s rural electrification experience with cooperatives undertaking grid extension managed to serve 40 million people between 1980 and 2007 (GNESD 2007).



in 1995 to 96 % by 2010 was largely achieved through grid electricity provision (Khennas 2012, Nygaard & Dafrallah 2016). Vietnam is another country where grid extension was the approach to rural electrification to achieve 98 % electrification by 2010 (Gencer et al. 2011). For the above countries, it can be argued that their contexts favoured grid extension; in that their rural populations were more densely populated and in closer proximity to grid infrastructure than may be found in poorer Sub-Saharan African countries (Nygaard & Dafrallah 2016, Bhattacharyya & Ohiare 2012). Yet in the Philippines which consists of more than 7100 islands, energy generation was in some cases conducted with generators mounted on barges to serve local grids, and in remote locations mini/micro-hydro systems were largely utilised to increase electrification from 19 % in 1969 to almost 90 % in 2014 (IEA 2009, Bhattacharyya 2012). It is worth adding that percentage access does not tell the entire story, and there have been some experiences of electrified households in China being dissatisfied with the service rendered due to unreliability and insufficiency of electricity supplied (Shyu 2013).

Important to the success of the above country experiences, particularly in China, was the incorporation of rural development as part of the electrification process, which meant that plans were put in place to ensure the energy systems adopted could facilitate local productivity, and accommodate future growth in energy demand (Bhattacharyya 2012). In acknowledging that one size does not fit all cases of energy poverty, it seems important that whatever solutions are adopted, there must be clear plans for local development and the potential to scale energy services to serve a growth in activities. Some accounts of Bangladesh’s SHS experience suggest it led to instances of increased incomes and new service-based businesses (Urmee & Harries 2011, Sharif & Mithila 2013); though it is unclear whether these largely inter-household benefits can spur community/local development. Nevertheless there are other implementation issues that were not touched on in this section that can dictate the suitability of the aforementioned technical solutions, and the tier of energy access they can make available to the energy poor over time. One such example of these non-technical considerations is the delicate issue of managing community relations; particularly relevant for the implementation of mini/micro-grid systems (Franz et al. 2014). This, and other issues concerned with greater private sector involvement with the commercial approach to energy access are reviewed in the section that follows.

### **3.4 Sustainable markets for energy access**

Efforts to develop a sustainable market for providing the energy poor with energy access began around the turn of the 1990s with the acknowledgement that: donor institutions, national governments, and other development practitioners (such as NGOs) did not have the resources — technical and financial — to provide the tailored solutions that energy poverty

required (World Bank 1996); consumers were most likely to appreciate and maintain their energy systems if they did not receive them for free (Sovacool & Drupady 2011); and the energy poor were willing to pay for the benefits brought about by energy access at prices sufficient to cover costs (World Bank 1996, IEG 2008). Under this commercial approach, governments and development institutions would stimulate private sector involvement by demonstrating the business case for what were untested technologies (i.e. decentralized renewable energy systems and technologies) in risky, low-profit markets (i.e. developing country rural communities) (ESMAP 2000). The results have been mixed; with difficulties scaling or replicating the most promising experiences (Bazilian, Sagar, Detchon & Yumkella 2010, Sovacool 2013a).

The business model of a commercial energy access project is concerned with ensuring the costs associated with energy service provision are recovered, and profitability is sufficient to grow the business and attract investment (Zerriffi 2011). Embedded within each business model is: the system or technologies used for energy supply; a dissemination mechanism that governs how energy services are to be made available to the consumer at a price affordable to them, over the lifetime of the system or contract; and the ownership structure of the business, which although commercially operated, can still be community-owned, or through public-private partnerships (Bardouille 2012). Increased private participation in energy access has brought about numerous approaches to serving the energy poor. It has led to the use of various technologies, from improved biomass stoves and alternative-fuel stoves for cooking, to solar lanterns, solar kits, SHS, solar kiosks and charging stations, mini/micro-grids, and the classic grid extension for lighting and other electrical uses; all of which require and have relied on various and ever evolving business models. Table 3.1 presents a broad typology of these approaches.

There is a large body of literature that gives particular treatment to the concerns of suppliers and the risks to business viability stemming from how their mechanisms, financing or otherwise, impact their ability to: manage consumer expectations (Wamukonya 2007, Ilskog & Kjellström 2008); ensure service quality (Lemaire 2011); collect fees (Lemaire 2009); alleviate energy system theft, vandalism and other non-technical losses (Palit & Chaurey 2011, Ilskog & Kjellström 2008); achieve scale (Glemarec 2012, Lopicard et al. 2017), and other aspects of market development (Steel et al. 2016, Yaqoot et al. 2016, Chaurey et al. 2012, Martinot et al. 2002). This section pays particular attention to the effect commercial approaches to energy access have had on the affordability and availability concerns of the consumer; reviewing whether or not it is possible to marry the needs of for-profit suppliers and the needs of poor consumers (Shrimali et al. 2011, Sesan et al. 2013, Bond et al. 2012), and how this may be impacting the development of sustainable universal energy access solutions.

**Table 3.1:** Typology of energy access supply models

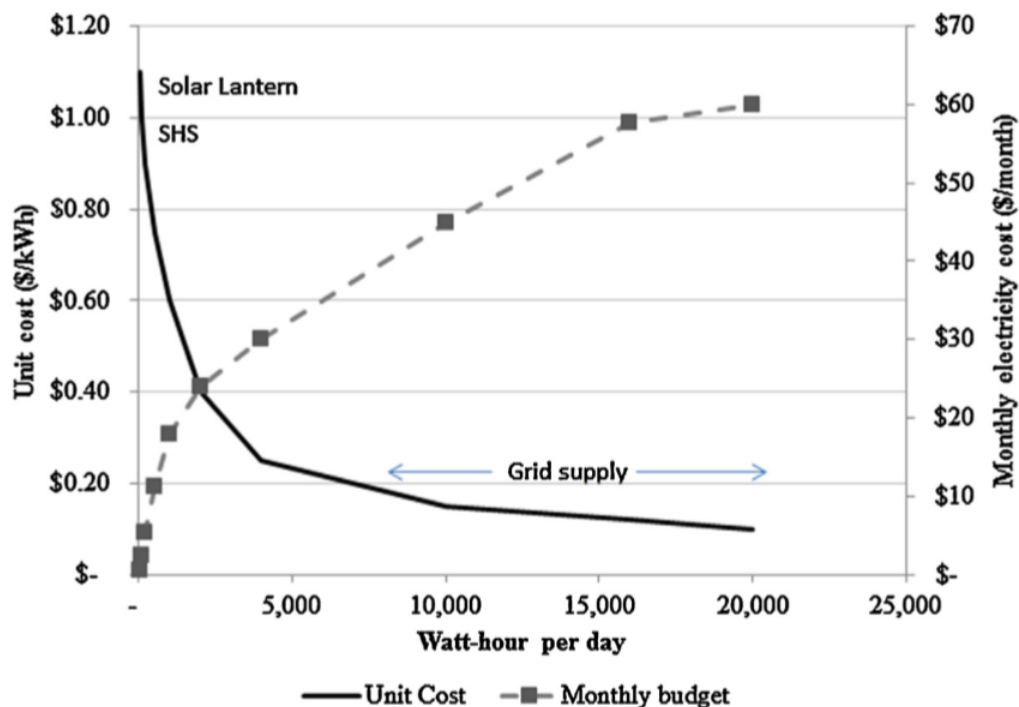
Business model	Grid Extension	Grid-connected/Isolated village mini/micro-grid	Stand-alone systems
<b>Private (for profit):</b> small and large coverage or concession; decentralized or centralized; product sales through to PAYG fee-for-service	Small grid reseller (India)	Diesel/hydro mini-grid (Cambodia, Ethiopia)	SHS, WHS, pico-hydro, solar kits (Bangladesh, Rwanda, Uganda, India, Brazil, Morocco, South Africa, Argentina, Mongolia, Nepal)
	Privatized concessionaire extends grid (Argentina, Chile, Guatemala, Uganda)	Hybrid mini-grid (India)	Solar lanterns (India, Indonesia, Kenya, Indonesia)
		Off-grid concessions (Argentina)	ICS and fuels (Ethiopia, Kenya, India, Ghana)
		Hydro mini-grids selling to local customers and grid (China, Nicaragua, Senegal)	Solar kiosk (Rwanda, Kenya, Tanzania, Ethiopia, Ghana, Botswana)
<b>Non-governmental or quasi-commercial:</b> partially subsidised technology in public-private partnerships; NGOs; Cooperatives	Cooperative finances grid extension (Bangladesh, Costa Rica, US)	Multi-service Cooperative mini/micro-grid (Bangladesh, Philippines, Bolivia)	Diesel gen-set or renewable energy to power school, clinic, or community centre (Argentina)
	Public-private partnerships (Morocco, Brazil, Guatemala)	Community micro-grids (Brazil, Cambodia, Honduras, Sri Lanka)	SHS, solar kits and lanterns (South Africa, Argentina, India)
			ICS and fuels (Mexico, Tanzania, Mali)
			PV battery charging station (Nicaragua)
<b>Public or non-commercial:</b> small and large; decentralized or centralized; primarily funded by public or donors	State-owned utility extends grid (Brazil, China, Cambodia, Thailand, Vietnam, South Africa)	Municipal diesel or hydro mini-grid (Bolivia)	Government or Multilateral development institutions providing SHS, solar kits (Mexico, Botswana, Ethiopia)
		Residual state-owned isolated diesel mini-grids with subsidies (Cambodia, Nicaragua)	Solar lanterns (Haiti, Afghanistan)
		NGO (Peru)	ICS and fuels (Kenya, Peru)

Source: Adapted from Reiche et al. (2006) and Bardouille (2012)

## Affordability and availability

In Section 3.3 the economic case for providing the energy poor with lower-load energy systems was discussed, and it represents one of the ways in which private sector innovation has sought to address energy affordability. This is the so-called ‘marketing for the Base of the Pyramid (BOP)’ (Hystra 2013, Hart & Christensen 2002, Terrado et al. 2008). Although the unit cost of smaller systems is higher than larger systems of energy delivery, energy consumption levels commensurate with larger systems places greater strain on the budgets of the energy poor (see Figure 3.1). The energy access field has witnessed 23 million sales of pico-PV energy systems in the developing world between 2010 and 2016 (REN21 2017).

**Figure 3.1:** Average daily electricity consumption and cost of supply from off-grid solar and the grid in some South Asia countries



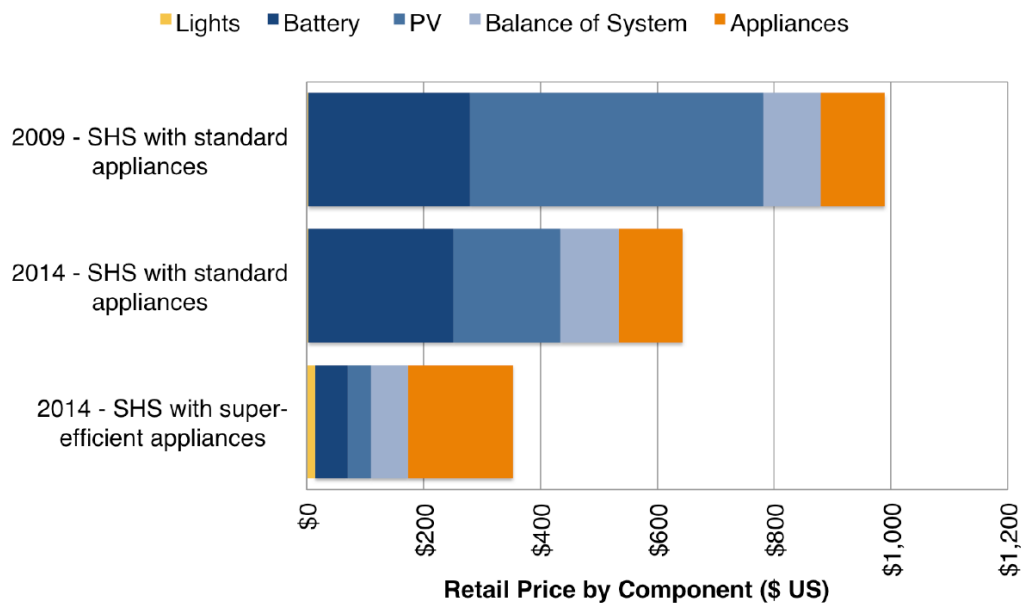
Source: Chattopadhyay et al. (2015)

When the alternative is a lack of modern energy and a reliance on dangerous biomass cookstoves and kerosene lanterns, it can be concluded that modern energy is being made affordable to the poor through smaller systems. This is how the development community has often viewed this issue (Chattopadhyay et al. 2015). However, others have disputed this presentation of affordability. Karnani (2007) argues that claiming affordability on the grounds of a reduction in size to suit poor people’s cash flow is a “fallacy”, stressing that the “only way to increase real affordability is to reduce the price per use” (ibid., p. 95). Therefore, efforts to increase the energy *efficiency* of cookstoves and appliances provided

with home systems, such as LED light bulbs, represent a more appropriate argument for innovation leading to increased affordability (World Bank 2015a).

What Karnani suggests is that actions that claim increasing affordability should provide decreasing costs for achieving the same activity. Innovations such as the LED lamp have been able to achieve this because their costs are low enough such that the drop in costs achieved by requiring a smaller system than would be required with an incandescent lamp is not off-set by the level of increase in the cost of the LED lamp; but rather achieves major price reductions to achieve the same activity (see Figure 3.2). Important developments in technological innovation is making it possible for useful (modern) household service demands — including television services, refrigeration and fans — to be made available to the energy poor at a fraction of prices required with standard appliances (Global LEAP 2016).

**Figure 3.2:** Retail purchase price for three solar home systems that provide identical levels of service



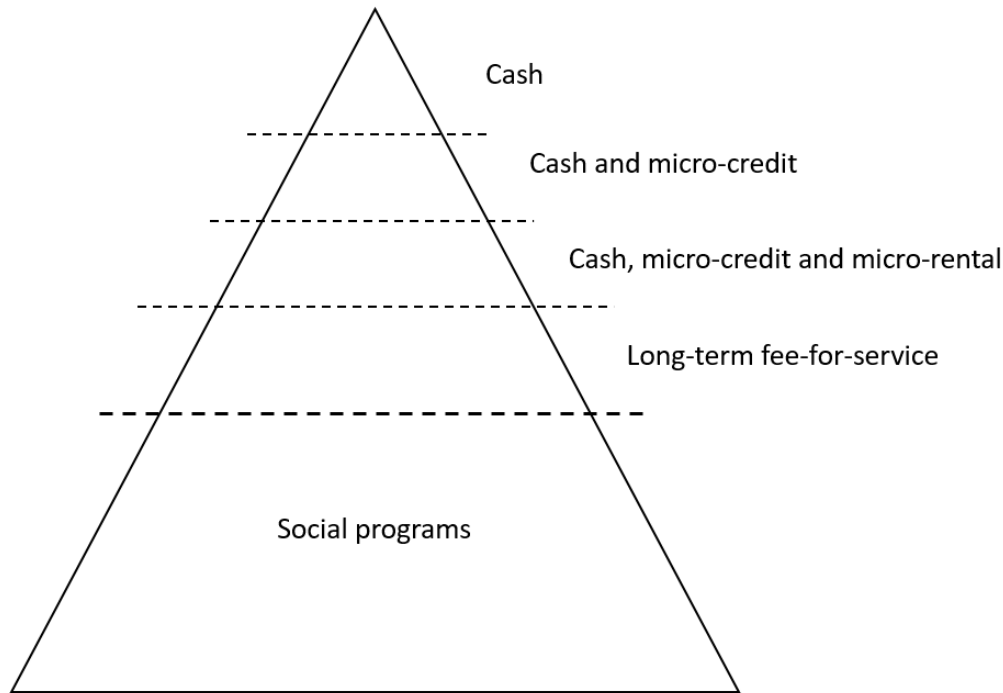
Source: Phadke et al. (2015)

Note: The level of service provided by the three solar home systems compared include; 600 lumens of lighting for 4 hours per day, operation of a 19inch colour TV for 4 hours per day, operation of a small portable radio for 6 hours per day, and a single daily charge for a basic mobile phone.

However, despite the smaller budget requirements of decreasing home-system sizes, the historical affordability barrier that makes it difficult for the poor to access a grid-connection is also present with the former's upfront cost; notwithstanding falling prices (IEA 2011a, Khandker et al. 2014, BNEF 2017). Typically, only the wealthiest rural households can afford to make upfront cash payments for a solar home system or an improved cookstove (ICS), so consumer financing mechanisms have been used to make these systems affordable to poorer residents (Martinot et al. 2001, Urpelainen & Yoon 2017). The aim has therefore been to

spread the upfront cost over a period of time, such that larger segments of the population will be able to afford the incremental financing requirements (Abdullah & Markandya 2012). As the ability to afford systems within the population lowers, the more flexibility is required in payment arrangements. One depiction of this flexibility requirement within a particular market can be found in Figure 3.3.

**Figure 3.3:** Affordability pyramid — energy poor market segments with accessible modern energy transactions



*Source:* Adapted from Terrado et al. (2008)

Arranging consumer payments such that they closely mirror prevailing energy expenditures in size and frequency, is the basis of providing affordability through each financing mechanism (Moreno & Bareisaite 2015, Alstone, Gershenson & Kammen 2015). An important difference between technologies for providing energy access is the fact that the reticulated forms (micro/mini-grid and grid) are limited to a financing arrangement that is based around some type of fee-for-service, since complex systems are used to serve multiple consumers. Whereas with the home-systems, the full range of options depicted in Figure 3.3 are applicable; although prudent business practice would aim to transfer ownership of the plug and play technology to the single consumer being served.<sup>9</sup> As a result, alternative financing

<sup>9</sup>It is beneficial for home-system suppliers to transfer ownership of systems to consumers as it reduces collateral (Lepicard et al. 2017, Moreno & Bareisaite 2015, Orlandi, Tyabji, Chase, Wilshire & Vickers 2016). Home systems differ from more centralized production and network distribution in that there is no main production system stationed at the premises of the supplier, as is the case with larger generators, and thus

arrangements to the cash model for commercial delivery of home systems have largely been based on credit extension to finance purchases (Moreno & Bareisaite 2015, Orlandi, Tyabji, Chase, Wilshire & Vickers 2016, Steel et al. 2016); evolving from partnerships between energy suppliers and microfinance institutions through to energy suppliers providing consumer financing in a one-stop-shop model exemplified in Bangladesh.<sup>10</sup>

This reliance on credit, as depicted in Figure 3.3, excludes a large segment of the energy poor due to a number of reasons: it allows limited flexibility to consumers to manage their costs through consumption (Moreno & Bareisaite 2015); some locals can be unacquainted/uncomfortable with debt (Sovacool et al. 2011); and given the informal nature of communities in which the energy poor reside, many residents may not possess the necessary collateral or credit-worthiness to be able to obtain a line of credit (Lepicard et al. 2017, Mulugetta et al. 2000). Experts have warned that credit to the poor does not necessarily aid poverty alleviation, particularly when it is for consumptive purposes as opposed to income-generating purposes (Armendariz & Morduch 2010). Karnani (2007) argues that as with the reduction in size approach, credit to the poor for consumptive purposes does not increase affordability. Essentially, the choice for cash-strapped consumers considering the purchase of modern energy technology is: save money for the necessary period of time (e.g. 1 year) and make a cash payment, or take a loan and make loan repayments over the allocated period of time. The benefit of the latter is ‘instant gratification’ from immediate service availability, but also comes with a cost relative to the former through specified interest rate payments per month; but there is no difference between the two regarding the customer’s affordability of the technology. Indeed, given the continued fall in the prices of renewable energy technologies, a cash transaction in one or two years could be more affordable to a consumer than being locked earlier into a two to three year contract for the technology (Baurzhan & Jenkins 2016).

Still, a large segment of the affordability pyramid consists of consumers whose monetary capability leaves them out of the market all together. These consumers are sometimes thought of as the people the IEA envision will be without access to electricity and clean cook-stoves respectively by 2030 (674 million and 2.3 billion people respectively according to their latest estimates; see Chapter 1. Sovacool (2014a) refers to them as “the poorest at the bottom of the energy ladder”, who are “too politically distant and...economically too costly”

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there is limited oversight on the operation of each system located at various locations; although developments in remote monitoring of home-systems has aided after-sales operations to the benefit of consumers and suppliers (discussed later in this section). Nevertheless, private suppliers providing home-systems on a fee-for-service model have been observed to face difficulties sustaining operations — thus affecting efforts to develop the market (see Steel et al. 2016).

<sup>10</sup>Bangladesh’s SHS programme was implemented by a state-owned financial institution IDCOL (Infrastructure Development Company Limited), through its partner organisations (POs) (Khandker et al. 2014). The responsibility of the POs included the selection of project areas and customers, offering micro-lending, installing systems and providing after-sales maintenance, and training users and local technicians (Palit & Chaurey 2011).

to serve with modern energy services (*ibid.*, p. 41). The historical argument against grid extension in favour of small-scale systems, and adopting a commercial approach to energy access is that the poor are not being reached (Palit & Bandyopadhyay 2016). The case to suggest that these unconventional approaches can bring about the needed affordability is not so clear; and it also affects modern energy availability. For example, in some markets the profit-oriented nature of private actors has led to a preference for serving the densely-populated urban energy poor (Lepicard et al. 2017); who exhibit a demand for SHS despite the availability of grid infrastructure, since grid supply is unreliable (between tiers 0 and 2 in terms of hourly service) and costly (Opiyo 2016).

Consumer discrimination (including within communities) emerged from some earlier experiences, where the remoteness of some rural energy poor consumers gave suppliers logistical difficulties that threatened business viability; for example during payment collections (Lemaire 2011).<sup>11</sup> When this inequality of provision takes place within communities, it can have a negative impact on local socio-cultural dynamics (Cook 2011, Winkler et al. 2011), which can — in extreme cases — lead to conflict. This was illustrated by locals during a study in Papua New Guinea (PNG) (Sovacool et al. 2011):

“a solar panel cannot be shared, cannot be distributed communally, so it does not fit with the core values, the cultural mores of PNG rural life. It is, therefore, determined to be offensive, and sometimes destroyed or removed as a result.”  
(*ibid.*, p. 1540)

The onset of Pay-As-You-Go (PAYG) financing mechanisms in recent times has been heralded as a major innovative breakthrough in alleviating some of the above logistical barriers that threatened business viability and excluded certain customers from the energy access market (Alstone, Gershenson, Turman-bryant, Kammen & Jacobson 2015, Odarno et al. 2017). This can be illustrated in the business model’s success in leveraging record levels of investment in the off-grid energy sector serving developing countries, consisting of \$223 million in 2016, an increase of 40 % from 2015 (REN21 2017).

Leveraging mobile infrastructure and technology for mobile payments (mobile money, scratch card, airtime) and machine-to-machine connectivity, PAYG-enabled off-grid systems have assisted both suppliers and consumers in alleviating business logistics issues and enabling financial transaction flexibility respectively; as well as enabling remote monitoring and control to allow contract enforcement, and data collation for improved service delivery and stronger supplier-customer relations (Alstone, Gershenson, Turman-bryant, Kammen & Jacobson 2015, Moreno & Bareisaite 2015, Rolffs et al. 2015, Smertnik 2016).

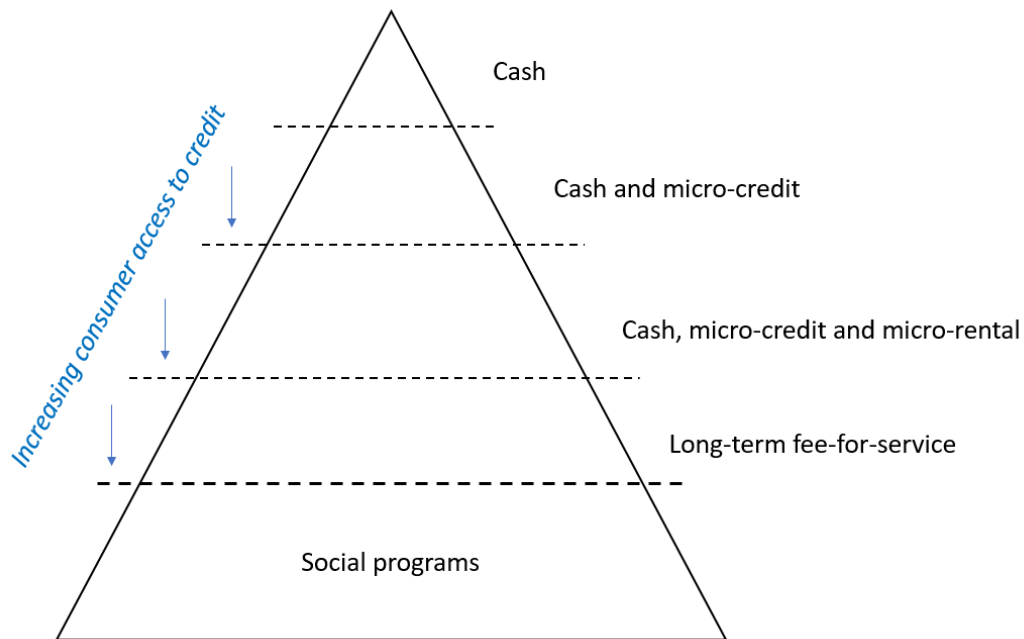
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<sup>11</sup>See Lemaire’s (2011) and (2009) publications for detailed evaluations on some of the issues faced by suppliers prior to the incorporation of PAYG-enabled systems.



PAYG features, a priori, increase the market segment that is expected to engage in commercial supply of modern energy services through the above features (see Figure 3.4). It does this through the contract enforcement mechanism that remote monitoring and control provides, since there is a difficulty with legal enforcement of contracts (unlike those existing in developed countries and formal markets of the developing world) in what are informal environments, and by opening up the opportunity for a wider variety of payment avenues through the use of mobile payments (e.g. third-party payments made by relatives residing elsewhere) (Lepicard et al. 2017, Orlandi, Tyabji, Chase, Wilshire & Vickers 2016). This means that a consumer can make more flexible payments for, and use of, their energy system in accordance with their ability to pay (Alstone, Gershenson & Kammen 2015). Nevertheless, as can be expected, there is evidence to suggest that the complexity of PAYG business models — particularly in the setup of arrangements that enable consumer understanding of, and engagement with, the technology, payment process, and conditions surrounding default — can make for difficult and costly operations, at least during the early stages of market engagement (Barrie & Cruickshank 2017).

**Figure 3.4:** Theoretical effect of PAYG on Affordability pyramid



*Source:* Adapted from Terrado et al. (2008)

*Note:* The use of PAYG with any one of the micro-credit, micro-rental, or fee-for-service consumer financing models is dependent on a range of supplier considerations; including the technical solution and the needs of the supplier's business model (Moreno & Bareisaite 2015). Therefore shifts in the market capture of each financing model indicated in the figure are not proportional indications of change.

The potential for PAYG-enabled systems to further modern energy access is indicative

of private innovation thriving with the assistance of ‘critical infrastructure’. It is the provision of telecommunications for mobile money services that facilitates this private sector innovation, and regions without this infrastructure will be unable to benefit. This suggests that private sector innovation cannot be used to circumvent poor levels of development in regions where the energy poor reside, but rather local development is required to assist private sector energy-innovation. Indeed, following two decades of slow progress in creating sustainable markets for energy access, Sovacool (2014a) emphasises the need to revise this commercial approach and points to the emergence of another. Describing this “new sustainable programme paradigm” to be more mindful of societal goals:

“It maintains a focus on polycentrism, or the involvement of multiple actors from multiple spheres. Programmes extend beyond technological diffusion and market viability to encompass goals such as environmental sustainability, the reduction of greenhouse gas emissions, and local job creation. Their focus is on energy services and income generation rather than fuels or equipment, but they still recognize the necessity of high quality, standardized, and certified technology. Evaluation and monitoring are continuous, after-sales service and maintenance are extensive, and communities share costs and in-kind contributions to projects...broader social and political factors must be promoted alongside technology and market development” (ibid., p. 50)

The private sector is expected to play an important role in making modern energy services accessible to the energy poor; not least because of the mammoth \$65–\$86 billion estimated annual shortfall in financing (2013 estimate) that needs to be plugged if universal energy access is to be achieved by 2030 (Pachauri et al. 2013, World Bank 2017a). Current trends to scale activities and financing include programmes launched by multilateral institutions such as the World Bank, or western governments (e.g. the U.S.’s Power Africa initiative), to facilitate partnerships with recipient governments, other development institutions, and social entrepreneurs to leverage private capital for scaling promising solutions (REN21 2016). While this is beginning to channel greater funding to the sector, the outcomes of these approaches seem to be at odds with an accepted prerequisite for sustainable solutions: local involvement and local capacity development.

### ***Strategies for access infringing on local involvement?***

The importance of involving local communities in the scoping, planning, and execution of energy access projects is because of a number of opportunities it presents; all of which contribute to the sustainability of a solution and the potential for its growth. Any technical solution needs to be able to respond to the context in which it is being deployed, and since contexts vary considerably, local insights provide an invaluable input to energy system

designs (Chaurey et al. 2012). Engaging with the necessary local governance structures from an early stage can influence local perceptions, which can have a significant impact on system security, behaviour change, and maintenance operations (IEA 2017, Scott 2017). A participatory approach could also draw on “the richness not just of the knowledge, but of the creativity and analytical abilities of villagers” (Chambers 1992, p. 38). Developing local capabilities for undertaking the ecosystem of value chain and institutional activities that characterise a functioning market for energy services — such as fuel production, technicians, technology development, legal and regulatory frameworks, etc. — is a major catalyst for sustained interventions (Han et al. 2014).

Since the calls for participatory approaches to development began in the 1990s (Chambers 1992, Westhoff & Germann 1995), its application in the practice of energy access is said to have been inconsistent (Herington et al. 2017). Conflicting project/programme/business requirements by implementing agencies often means “the needs of customers are presumed and their roles prescribed” (Sebitosi & Pillay 2005, p. 2045). Potential conflicts from a programme sponsored by an external development institution can be seen with the example presented by Troncoso et al. (2011). In this case, the pressure applied on an NGO to honour its programme commitment — which was to build 1,500 improved cookstoves in five years — led them to neglect understanding user needs and opinions, and abandon the two-way learning and iterative process for establishing new technology; deciding rather to “convince” users to use the technology (ibid., p. 7604).

The expectation is that with the more commercially-oriented approaches, the relation between social entrepreneurs and their investors will be less restrictive and accommodate whatever practices will generate profit (Zerriffi 2011). However, the characteristics of private enterprises operating in the energy access sector threaten to reinforce limitations on the role of local people. For example, in a report that highlights best practice for rural electrification policies, the IEA clearly articulates — as one of its preconditions for successful stand-alone system interventions — the need for “locally produced and resource-specific technologies for electrification” to “reduce the need to import systems” (Niez 2010, p. 9). But in many SSA countries, where energy poverty is most acute, there exists a bias towards the promotion of imported solar resource-based technologies, despite an abundance of other locally-relevant renewable resources (Campbell et al. 2016).

The benefit of solar energy as a relatively easier fuel to harness than some other local fuels — such as biomass related fuels — makes it an attractive choice. But the ease of access to the fuel is but one of a number of aspects that must be considered before useful energy is provided to households, and the factors governing these aspects can make this process favourable in one context, and difficult in another. The components of the system being imported, exchange rates, size of market and other market demographics, and the capacity

for supportive policy mechanisms, *inter alia*, all have an impact on the economics and practicality of solar PV technologies (Bazilian et al. 2013). Nevertheless, foreign practitioners and development institutions lobby host governments indiscriminately to lower barriers to the importation of solar technologies (Campbell et al. 2016), with limited activity to develop local technology development capabilities.

This desire to facilitate technology imports is a symptom of the current nature of private involvement in the energy access market, and the limited role of local communities in designing their energy solutions. The majority of enterprises that have successfully partnered with development institutions and foundations to leverage impact and commercial investment are either headquartered in western countries or have parent companies domiciled in developed nations (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016, REN21 2016). Therefore, the manufacturing hubs of off-grid technologies, such as SHS and ICS, exist outside the countries in which they are being deployed — with China constituting a major manufacturing base (World Bank 2011*b*, Urme & Gyamfi 2014). There are a few examples of local companies that have engaged in some level of manufacturing capabilities in ICS and small-scale solar lantern technologies (see Bardouille 2012). Nevertheless, it has been said that western development organisations have a tendency to favour partnerships with trusted home-based firms, in a bid to ensure efficient utilisation of funds to obtain their desired outcomes (Natsios 2010). But such an approach can hinder the development of local capabilities (see Kozloff & Shobowale 1994).

The role of local enterprises in many energy access markets centres on micro-franchise retailing (van Gevelt & Holmes 2015, McDade et al. 2014). In-country product development is typically limited to product (dis)assembly (Hirmer & Cruickshank 2014*a*). These entrepreneurship opportunities are an important area of local empowerment fostered by the commercial approach to energy access; serving to create income generation opportunities for locals that partake (McDade et al. 2014). But at the same time, the development of a network of micro-franchises can be argued to be of greater benefit to operations of foreign wholesale technology suppliers, than it does the position of local communities as stakeholders in the development of their energy services (Campbell et al. 2016, Sesan 2014). Leveraging the skills of local artisans developing tailored technologies to local preferences with shorter turnaround times has proved an effective way to grow the market (Adkins et al. 2010). But this also comes with the risk of substandard products failing or spoiling the market (Lysen 2013, Kees & Feldmann 2011). There is therefore a need for quality assurance mechanisms in order to develop the market (Mills et al. 2015); but it seems a measure of flexibility is also needed to avoid indirect suppression of local product development and consumer access (Urpelainen 2016).

Karekezi & Kithyoma (2002, p. 1082) take a wider view on the impact of SSA countries

relying on technologies with high import contents, such as PV technology; highlighting that the additional stress they place on limited, and perhaps dwindling, foreign exchange reserves “is not good macro-economic practice”. van der Vleuten et al. (2007) challenged this by drawing attention to the fact that if the alternative is a reliance on petroleum-based energy, many developing countries would still need to rely on imports, with higher stress placed on foreign reserves than that of small-scale solar technologies. Both arguments are correct in highlighting the pressure that high import contents of energy consumption can place on foreign reserves of poor countries. What seems to be important is that when the import content can be minimised, strategies to do so should be adopted. Countries cannot choose what natural resource endowments they possess, but they can develop capabilities in the production of select key components of energy systems (Schmidt & Huenteler 2016).

Domestic technical capacity building may well have, as the above perceptions have indicated, important implications on affordability, local development, and market sustainability. Indeed, the Ghana Solar Project, which managed to grow the SHS market in energy poor regions of the country, was observed to be vulnerable to unsustainability; due in part, to a lack of local technicians and a scarcity of spare parts for much needed maintenance, replacement, and repair operations (Steel et al. 2016).

There seems to be tensions surrounding this subject; which can be illustrated by Bauzhan & Jenkins’s (2016) claim that at current prices of stand-alone solar systems, “unless the technology is subsidised from abroad...the only clear beneficiaries are the commercial interests in developed countries” (ibid., p. 1412). This consideration of the equity and justice of energy access prescriptions has other dimensions of debate, in the face of growing concerns over potential trade-offs in simultaneously addressing climate change and energy poverty. A discussion on this goes beyond the scope of this review but for detailed perspectives see: Casillas & Kammen 2010, IEA 2011a, Panos et al. 2015, Chakravarty & Tavoni 2013, Wolfram et al. 2012, Gertler et al. 2011, Moss et al. 2014, Moss & Leo 2014, Cherian 2015.

### **3.4.1 Insights from successful countries: market development**

Countries with relatively successful experiences adopted some mix of state support and leadership, and market-based mechanisms; but local involvement, local capacity development, and often local ownership were important components of their electrification and cookstove programmes. Morocco’s rapid electrification achievement is said to have been achieved through strategies that incorporated local stakeholders as partners, along with the government, and other stakeholders from developed countries (Khennas 2012). For example, under the country’s rural electrification programme the national utility was given a dedicated office to manage the programme at the national level for both grid and off-grid solutions, but

also had decentralized offices to collaborate with local partners; the latter of which included local municipalities that approved zones, identified houses, provided information and financing (Nygaard & Dafrallah 2016). In Cambodia, the reliance on local manufacturing for a cookstove programme that has disseminated over 2 million improved cookstoves since 2003 is said to have fostered local multi-stakeholder coordination that has been crucial to the success of the programme (Simon et al. 2014, Benoist 2013).

Bhattacharyya (2012) contrasted the electrification experiences in China and India between the 1950s — when they both initiated their electrification activities — and early 2010s; with China representing the perfect example of local involvement, using locally relevant resources for local solutions for success, while India’s apparent neglect of these still left a substantial percentage of its population without access (52 % electrification rate in 2011 (Palit & Chaurey 2011)). Acknowledging that within its borders local community contexts will differ and require various solutions, China opted for projects across the country to be administered and implemented by local institutions. This would require technological diversity for locally-relevant energy resources, which was facilitated by domestic manufacturing capacity able to exploit scale and scope economies to lower costs along the value chain; therefore increasing end-user affordability (Bhattacharyya & Ohiare 2012). Whereas in India, it was observed that attempts to extend electricity access to the poor saw minimal local participation, ownership and resource use, ultimately leading to poor supply and supplier and consumer dissatisfaction (Bhattacharyya 2012).<sup>12</sup>

Crucially though, local capacity and infrastructure building is not an easy feat. It is observed to have taken China over 40 years to become a world leader in biogas production, which involved strategic implementation of research and development, pilot studies, training, and the development of a domestic value chain (Bhattacharyya 2012, Yisheng et al. 2002, Catania 1999). Key here is ‘strategic implementation’. With global activities still largely aimed at attracting investors, proving business models are ready for scale, removing barriers to business operations and building consumer trust across regions, countries, and communities, there may be an inherent difficulty in being strategic. Something for the global community to be mindful of, is to ensure the current sea of commercial energy access activity does not result in uncoordinated clusters of interventions that provide incremental achievements.

The fragmented manner in which donor institutions, private practitioners and financiers engage with energy access has been unable to develop the full range of institutions, capabilities and activities required to support markets (Tigabu et al. 2017, McHenry & Doepel 2015). It seems that any polycentric approach will need some form of indigenous leadership,

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<sup>12</sup>It should be noted that India has since achieved rapid progress in electrification to a rate of 82 % in 2016; largely through grid extension (99 % of new additions since 2000), and fuelled by coal (75 % of new generation since 2000) (IEA 2017).

upon which local involvement and capacity development can be built — beyond the confines of a specific project. It has been suggested that the institutional stability provided by the Chinese government in establishing robust support systems for local wind power — through research and development, feedback evaluation studies, creating supply chains, and developing relevant knowledge and skills within the local community — was key to allowing a research project grow to widespread use over a 20-year period (Leary et al. 2012). Similarly, the involvement of the Moroccan royal family in providing national direction for the development of the country’s renewable energy activities has been cited as critical to the gains evidenced (Vidican 2015, Gruber et al. 2017). It is worth noting that the socio-economic conditions of these two countries and their capabilities are notably dissimilar to those of many developing countries, particularly in SSA; so it does raise the question of what sort of support poorer countries should be receiving in the bid to solve energy poverty in these areas.

Trends over the past few decades for geographic and subsector destinations of foreign direct investment (FDI) and development finance for energy projects, suggest that business and geopolitics are key determining factors, as much as country requirements (Miller & Hope 2000, Barnes et al. 2010, Bhattacharyya 2013, IEG 2008, Banerjee et al. 2014, Martinot et al. 2001, 2002, Zhang 2014, Bazilian et al. 2011). With respect to development finance for energy access; in the 1970s/80s the focus was Latin America and East Asia, in the 1990s/2000s South Asia received major attention, and more recently Africa is gaining increasing focus (IEG 2008, Terrado et al. 2008, Martinot et al. 2001, Bhattacharyya 2013, USAID 2016, Barnes 1988). Unsurprisingly, FDI has tended to follow concessional loans (Bhattacharyya 2013). There exists competition for resources — capital, human and otherwise — not just across regions and nations, but within country borders; and there is a risk that the least developed countries will be left out (Bhattacharyya 2013).

### **3.5 The demand for energy access**

Some of the difficulties encountered with the energy access market stemmed from perceptions of consumer behaviour that were largely based on monetary signals and technical benefits. It was expected, for example, that once modern lighting services can be supplied at prices lower than the energy poor’s kerosene expenditure — with the former also providing higher quality lighting amongst other benefits — then consumers would forfeit their kerosene consumption for modern lighting (ESMAP 2002, IEG 2008, World Bank 1996). However empirical evidence has shown many instances of households making use of both their previous traditional and new modern energy services concurrently for various reasons beyond that of price/income or technical performance: a situation described as ‘energy stacking’ (discussed further in Chapter 4). For example, in India wealthy households that could af-

ford modern fuels retained fuelwood stoves for the purpose of baking traditional bread (IEA 2006). In rural Mexico, it was found that despite observing circa 60 % in energy savings from modern cooking stoves, households did not discontinue their use of traditional open fires for certain tasks (Berrueta et al. 2008). Similar observations were made for kerosene and SHS use in Bangladesh (Komatsu, Kaneko, Shrestha & Ghosh 2011). Evidence also shows the energy poor maintaining use of traditional lighting in order to prioritize energy from SHS for television services (Martinot et al. 2002).

It seems, that traditional and modern energy compete to serve varied and context-specific consumer needs; most of which are yet to be fully understood from the perspective of the energy poor. Jeuland et al. (2015) lamented that surprisingly little was known about what households appreciate about energy products. Using a sample of 2120 rural households in northern India, they find that households have a strong baseline reliance and preference for traditional stoves over improved cook-stoves (ICS); where their willingness to pay (WTP) for the ICS — that could bring meaningful benefits to their health and fuel expenditure (with a 33 % reduction in smoke emissions and fuel requirements respectively) — only reached 50–75 % of the market price. As a result, they suggest the need for supportive policy beyond that which will support supply, but that which will galvanise demand for ICS. In some cases, traditional cookstoves act as much more than just a cooking service, but as important sources of lighting and heating to facilitate social gathering (Bielecki & Wingenbach 2014). If potential replacements sacrifice these important cultural and social needs of local people for gains in efficiency, there is unlikely to be a displacement of the inefficient traditional stove.

If the adoption of modern energy services does not then mean the discontinuation of traditional energy services, can we definitively say that energy access is addressing the welfare and development concerns of energy poverty? Traditional forms of cooking present arguably the most urgent household energy poverty issue, with an estimated direct contribution to 3.5 million deaths globally per year (fourth only behind high blood pressure, alcohol, and tobacco) (Lim et al. 2012); also possessing a strong gender dimension. These statistics justify the need for the international community to take clean cooking seriously, as indicated with the IEA’s special report on indoor air pollution (IEA 2016). Yet, there is much evidence to suggest that addressing the above risk may not be central to the thinking of local people.

One example from experiences in India found that villagers were not concerned about addressing their traditional cooking systems by switching to biogas, instead they were more concerned about getting clean water services, and supported the use of biogas for electricity generation (World Bank 1996). Other studies cited one form of clean cookstove displacing another clean alternative as opposed to displacing traditional cooking fuels (Banerjee et al. 2016, Andadari et al. 2014, Kebede et al. 2002). Evidence is suggesting, worryingly, that



health benefits do not seem to provide much marketing appeal to local users (Thurber et al. 2014, Bielecki & Wingenbach 2014); so much so that Johnson & Bryden (2015) highlight that perhaps more attention should be given to cookstove safety, as it pertains to reducing hazards and resulting injuries, where users may find greater value given the *salience* of these risks. It should come as no surprise to practitioners that households are not suitably placed to consider the social externalities the global community is concerned with, particularly because indoor air pollution is a silent killer; and thus, myopia plays a part given the other pressing issues poor people are faced with on a daily basis under severe monetary constraints (Collins et al. 2009).

This is not to say that households do not value improved cookstoves, on the contrary; Loo et al. (2016) found that women in western Kenya preferred ICS over the traditional (three-stone) biomass stove for reasons such as the ease of use, fuel efficiency, and perceived reductions in smoke and improvements on their health. But the multifaceted manner in which consumers engage with, and find value in, their energy services suggests the need to frame energy access beyond the current supply-centric technology and finance activities, to encompass a broader agenda that acknowledges the cross-sector and system-wide transformations that must take place as the demand and supply for energy services ‘transition’ from traditional to modern energy (Sokona et al. 2012, Ockwell & Byrne 2016, Tawney et al. 2015). By adopting transition-thinking, we begin to acknowledge that modern energy provision does not guarantee that households realise the full range of benefits anticipated by implementers (Ruiz-Mercado & Masera 2015).

It is right to question the significance of energy stacking on the goal of energy access, and whether or not the realised benefits to the energy poor from some form of modern energy engagement is not enough to justify current activities, when the alternative could be complete reliance on traditional energy services (Brooks et al. 2016). But if it is possible for solutions to be implemented such that households can discontinue engagement with, and consumption of, poor energy forms, then this would be a more efficient use of scarce resources. Especially considering that by some estimates, the use of a traditional cookstove for as little as 10 mins per day is detrimental enough to its users (Johnson & Chiang 2015). Furthermore, there remains uncertainty on the technical ability of some modern energy technologies to take households out of energy poverty. For example, in the case of modern cooking technologies, it is unclear whether the technical capabilities of recent options are meeting the minimum requirements to validate welfare benefits.<sup>13</sup> Couple this with energy stacking, and ‘cooking energy access’ risks being an exercise in name only, lacking substance.

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<sup>13</sup>Improved biomass stoves promoted in recent years have been judged by the WHO to have not come close to achieving the low particulate matter emission levels required to be beneficial for households (WHO 2014).

## 3.6 Research agenda

In the bid to bring modern forms of energy, and welfare-improving services to the energy poor, there is an understanding of the need to foster innovation in financing and deployment of solutions, relevant to changing contexts. This is an important area of research; in particular, how this can be achieved in some of the poorest regions of the world, in an equitable manner that does not marginalise local perceptions, priorities, voices, capabilities, and other local requirements. After all, the experiences discussed in this chapter suggest that the above considerations are important for sustainable solutions. Addressing this research need is not the main focus of this thesis, but discussions had will consider, and speak to, related issues; such as stakeholder involvement and responsibilities, and the useful role of different solutions.

The reality of energy stacking, the uncertainty it places on the impacts of modern energy provision, and the potential opportunity to address any constraints it places on energy access solutions, makes it an important area of research. This thesis examines this, and other household energy access issues, by researching the energy behaviour of the energy poor. The examination of household energy behaviour is not new, and this section will begin by reviewing some of the approaches adopted to generate knowledge on this issue; identifying opportunities for original work, before outlining the research questions answered in this thesis.

### 3.6.1 Methodological observations

Studies attempting to measure real savings or benefits of modern energy use, amidst energy stacking, by analysing quantitative survey data can be reliant on assumptions about household behaviour, stove efficiencies, the socio-economic attributes of significance, and be open to errors from household self-reporting (Vahlne & Ahlgren 2014, Thomas et al. 2013, Wilson et al. 2015). In clean cooking research, attempts to overcome these drawbacks have been found in studies that add, to surveys, direct measurements of fuelwood use and temperature dataloggers that serve to verify the data generated (Bauer 2016, Brooks et al. 2016, Piedrahita et al. 2016); although the monitoring of energy usage introduces potential household-behaviour bias from participants that know they are being observed (Thomas et al. 2016). A consistent acknowledgement of these studies is the need for further work that improves our understanding of the drivers of traditional and modern energy use (Piedrahita et al. 2016, Bauer 2016). In one instance, the provision of two improved cookstoves was unable to deter substantial reliance on traditional cookstoves (Piedrahita et al. 2016).

Thus, there has been no shortage of calls for greater use of social science methods and concepts for more robust examinations concerning energy access (see Mehlwana 1997, Sovacool 2014b), and academic scholarship in this field has been paying increasing attention

to these calls (Schillebeeckx et al. 2012). Understanding the drivers of behaviour among the energy poor will particularly benefit from human-centred qualitative research to complement some of the quantitative survey approaches discussed above; studies that can be exploratory, holding fewer preconceived notions about the determinants and nature of energy service adoption or use (Bryman 2016).

Close-ended surveys or research questions — that seek to test the significance of relationships, or seek to accept or reject a given hypothesis — are an important strand of energy poverty research as they allow us to establish and refine what works and what does not. For example, such studies can test the importance of monetary, informative, or social factors on the technology performance gap between lab tests and real-world usage (Bensch et al. 2015); or the importance of information on the willingness of consumers to adopt modern energy services (Beltramo et al. 2015). But answering the ‘why?’ and ‘how?’ questions about energy stacking and energy transitions respectively, require studies that examine the perspectives of users and their lived experiences to glean new insights about drivers and areas of current neglect (Schillebeeckx et al. 2012, Shyu 2013, Pachauri & Rao 2013). Studies that reveal, that just as developed country energy consumers make use of different cooking energy converters for different meals (e.g. kettle to boil water, toaster to toast bread, etc.), so too do the energy poor choose to apply different fuel-technology combinations for different cooking functions — and thus stack their energy (Ruiz-Mercado & Masera 2015). Or studies that reveal the role of social networks and community opinion leaders, and the social processes that facilitate the diffusion of new technologies (Ramirez et al. 2014).

The nature of the energy transition process is something to be monitored over time, as is the sustainability of energy access activities. This is why programmes cannot determine their success, for example, by the number of stoves distributed (Troncoso et al. 2013, Ruiz-Mercado et al. 2011, Pine et al. 2011). The respective cookstove programmes conducted by the governments of China and India beginning in the 1980s both managed to disseminate millions of improved stoves (Kishore & Ramana 2002, Xiliang & Smith 2005). But over 20 years later, virtually none of the latter’s disseminated stoves remained in operation (Adler 2010).

Achieving sustainability from the demand perspective has been attributed to matching solutions with local preferences (Miller & Mobarak 2014). The “success of solar hot water heaters in several countries, micro-hydro in Nepal, and wind-turbine water pumps in Argentina during the 1980s...the ethanol vehicle fuel program in Brazil” were all because they required little change in consumer behaviour (Martinot et al. 2002, p. 314). Investigating the extent to which local preferences can be matched with modern energy can make use of short term examinations, i.e. 1–3 years after the fuel/technology is adopted or a project begins, as they elicit insights about user experience of modern energy services vis-à-vis their

traditional energy experiences. Much useful research of this nature is ongoing in this field; eliciting insights from user-discussions surrounding the factors influencing adoption and short-term impacts of modern energy access (Banerjee et al. 2016, Barrie & Cruickshank 2017, Urpelainen & Yoon 2017, Yenneti & Day 2015, Collings & Munyehirwe 2016, Ulsrud et al. 2015, Troncoso et al. 2007). However, in order to closer examine the causes, processes, entrenchment, and perpetuity of important realities, such as energy stacking, perspectives surrounding energy adoption and usage beyond the short term is needed.

For example, it can be observed over a 1 to 3-year project that social networks and opinion leaders may influence — to a notable extent — a household’s decision to adopt a stand-alone energy technology when there is limited information about the technology amongst the target population; after which, experience making use of the technology will determine whether it maintains its place as one of the household’s energy services (Miller & Mobarak 2014). But if it is adopted as part of an energy stack (as is often the case), the circumstances that determine and explain the energy services’ role from minor or major use to complete traditional displacement or modern technology discontinuation, do not often manifest within such a short period of observation.

Some qualitative studies have accounted for a longer period of time in their bid to assess the outcome of particular projects, or features of a project: such as the merits of the community charging station model in Sierra Leone (Munro et al. 2016); or the socio-economic and environmental impacts of an improved cookstove project in rural Mexico (Berrueta et al. 2017); or the user factors that affect the sustainability of an off-grid solar plant project in the Philippines (Hong & Abe 2012). These studies provide valuable insight on the performance of energy access projects in bringing local people out of energy poverty. But where they provide knowledge and lessons for other contexts with evidence on the household behaviours and transitions possible with a particular energy access solution, in a given context, they have less room to put the household at the centre of examinations, rather than the energy solution. This leaves out important dynamics for learning; including, but not limited to, the influence of the traditional energy services — to be replaced — on observed behaviour.

Quantitative longitudinal studies such as those aiming to identify the significance of factors influencing observed energy consumption statistics (Joshi & Bohara 2017), often take a much longer-term view of their case as it is useful for examinations to rely on historical information going back decades in some cases. They are also at greater liberty to structure studies beyond post-project examinations (Campbell et al. 2003). However, there is a dearth of user-centred qualitative studies in this field that adopt such approaches.

Therefore, one opportunity to further understanding of the energy transitions of the energy poor, is a qualitative study that will not only elicit insights by examining household

engagement with the energy services beyond the short term, but will also elicit insights about transitions outside the confines of a dedicated energy access project. The former point is due to reasons around observing the process of the transition explained above. The latter, can eliminate some of the biases and/or constraints that dedicated projects entail. For example, as mentioned earlier, highly controlled trial projects/studies to monitor and test the behaviour of the energy poor upon access to modern energy services can influence behaviour which ceases to exist once the project is over. Northcross et al. (2016) tested the impact of bioethanol cookstove provision on maternal and neonatal outcomes in Nigeria, and part of their findings was the complete “substitution” of kerosene stoves with bioethanol stoves as opposed to energy stacking. As the authors rightly acknowledge; free provision of the stove and fuel over the course of the study may have impacted usage rates, since the participants were not required to purchase their stove nor fuel requirements. They mention that 76 % of the participants have chosen to purchase the ethanol fuel following the conclusion of the study, but the impact monetary contributions for the fuel may have had on kerosene engagement going forward is not known.

Furthermore — and more specific to most energy access projects, and studies with even less stringent testing controls — the focus on post-project examinations and the current emphasis in the field on energy resources, systems, and technologies has led to isolated and fragmented research and projects explicitly focused on a particular resource, technology or service. Academic scholarship in this field, not exclusive to qualitative studies, is prone to choosing a modern energy service it wishes to focus on; i.e. the sustainability of or user behaviour with solar lanterns for lighting (Hirmer & Cruickshank 2014a, Sharma & Palit 2014, Scott 2017, Collings & Munyehirwe 2016, Kornbluth et al. 2012), or SHS for electricity (Lay et al. 2013, Steel et al. 2016, Urpelainen & Yoon 2017, Bond et al. 2012), or mini-grids for electricity (Yadoo & Cruickshank 2012, Hong & Abe 2012, Shyu 2013), or improved cookstoves for cooking (Sehpal et al. 2014, Ruiz-Mercado & Masera 2015, Bensch et al. 2015, Troncoso et al. 2013), with very little examination of the interactions between the different energy forms and energy services. Yet, user interactions with energy services do not take place in isolation. Instead, they involve trade-offs and synergies across different activities and the (energy) services used to fulfil them. As Sovacool et al. (2012, p. 718) highlight, a lack of access to modern energy services that facilitate any one of lighting, heating or cooking, mechanical power, or mobility “can inhibit or exacerbate the use of others. For example, lack of access to mobility can influence the availability or price of kerosene (lighting), fuelwood collection times (impacting heating and cooking) and transporting processed products to market (mechanical power)”.

Thus, there is a need for research that takes a holistic perspective on household engagement with their energy services; particularly for understanding the determinants of

behaviour. Project-related analyses that shine a spotlight on a particular energy service or technology may find it hard to facilitate this understanding of the complexity of energy behaviours.

### 3.6.2 Research questions

There have been calls to consider energy access as a process that involves transformation of not just the energy services supplied to the energy poor but of the ecosystem of infrastructure, value chain institutions, knowledge, and other characteristics and capabilities that guide a household or community's transition from traditional energy services to modern energy services (Ockwell & Byrne 2016, Sokona et al. 2012). The practice of energy stacking supports this call and encourages questions on what type of energy access the international community should be striving for.

This thesis will inform the field by shedding light on the nature of household energy transitions, applying original research strategies that facilitate atypical examinations of the scope and drivers of energy behaviour change and sustainability. A better understanding of how the energy poor transition in their energy services, will aid informed decisions about the energy solutions and policies required for the desired outcome; all in the aim of ensuring universal energy access is sustainable and brings about human welfare and development. The questions answered in this thesis begin with a theoretical exploration of household energy behaviour and transitions in developing countries, to answer the first research question:

1. What explanation can be given for the energy behaviour of the energy poor, and thus, the nature of their transition to modern energy services?

The work will also use a relevant energy poor region in Lagos, Nigeria to address the further two research questions set out in Chapter 1:

2. What do the lived realities of households in rural Lagos reveal about the energy decision-making of the energy poor, and the drivers of sustained behaviour change?
3. How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways of relevant drivers, and what can this inform about facilitating the transition to modern energy services?

These questions and the methods by which they are answered are addressed throughout the remainder of this thesis; beginning with Chapter 4, which addresses the first research question to produce a conceptual framework for understanding energy-poor transitions, upon which the rest of the research will be framed. The justifications behind selecting Lagos as a case for answering the above research questions are discussed in Chapter 5

### 3.7 Conclusion

This chapter reviewed some English-speaking literature in the field of energy access to observe perceptions and ongoing debates on universal energy access. Given the evidence on impacts of modern energy use on the energy poor, there remain some uncertainties in the direction of action required to achieve the global goal, and how to address some ongoing issues. Some of these uncertainties include whether or not there is merit in prioritising energy access to particular demands, such as productive versus consumptive activities; and if so, what the priority should be. This becomes even more important with the understanding that there is a notable difference in resource-needs when aiming for different tiers of energy access. Another area of uncertainty involves the attempt to foster increased financing and innovation in the sector. The private sector has a major role to play in this regard, and has had a positive effect on energy access; not least with the innovation of PAYG-enabled systems, which have the potential to make modern energy accessible to an increasing proportion of the energy poor. However, increased private involvement to serve what are vulnerable, poor, base-of-the-pyramid consumers brings its own challenges; particularly when the target is *universal* access. It is not yet clear how best to foster the important pre-requisite of local involvement, amidst growing private activity. A key knowledge gap, which has the potential to inform efforts to address the above uncertainties, is a deeper understanding of how and why households interact with energy services the way they do; particularly because the practice of energy stacking has the potential to undermine efforts. This thesis aims to contribute to the useful work ongoing in this field, by adopting a methodological approach that explores the household-energy interaction from a unique viewpoint in its bid to further understanding of the energy transitions of the energy poor. The remaining chapters of the thesis present the methods and output of research undertaken; beginning by addressing the first research question in the next chapter.





## Chapter 4

# The Concept of Sustainable Household Energy Transitions

*What explanation can be given for the energy behaviour of the energy poor, and thus, the nature of their transition to modern energy services?*

**Research Question 1**

## 4.1 Introduction: Observing energy transitions

Energy transitions are generally considered in terms of changes to an energy system at any stage of its value chain, including changes to any one of its systems of production, transportation, and transformation (Goldthau & Sovacool 2012, Grubler 1991). In this chapter there is a focus on transitions envisioned in consumer energy use, and this can be as a result of changes at various points of the energy system; be it in the primary resources being used (fossil fuels, renewable energy), the conversion technologies used to generate useful energy (refrigerator, automobile), and/or the energy services being undertaken to satisfy a particular activity (lighting, cooking, transportation, information services). These changes can be observed at various scales (global, national, state, community, household), which lend themselves to a diverse range of theories and concepts explaining various aspects of the transition.

A simple definition of an ‘energy transition’ in the context of consumer use is the all-encompassing, albeit somewhat ambiguous, description used by O’Connor (2010, p. 8): “a particularly significant set of changes to the patterns of energy use in a society”. As with other ubiquitous terms used in the energy field — such as those discussed in Chapter 2 — there is no agreed definition of the concept, and different efforts to operationalise the term can have a major bearing on how pertinent questions are perceived. For a simple example; different specified thresholds on market capture to denote a transition, can impact its perceived temporality.<sup>1</sup> Some energy transitions are triggered as a result of opportunities presented by new discoveries or inventions; such as with coal resource discoveries, the steam engine, or the electric light bulb (O’Connor 2010). But in the case of energy poverty, the energy transition involves *purposive action* to address an existing problem, with a desired destination (Sovacool & Geels 2016). In simple terms, this destination is for universal human reliance on low-carbon modern energy services.

At the global, national, state, or community level, the extent of isolated or system-wide transitions of energy use can be observed in terms of *market share*, where concepts seek to explain patterns of uptake across different segments of a particular market, as well as the prosperity of the market for a given resource over time. Prominent among the technology adoption literature is Rogers’ (1995) diffusion of innovations theory, which explains the process by which an innovation is adopted over time among the members of a social system. Evolving from the above and other transition and technology development concepts (such as Gregory Unruh’s concept of the carbon lock-in for understanding macro-level barriers to diffusion (see Unruh 2000)), include those seeking to explain the transition pathways

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<sup>1</sup>For in-depth discussions on perceptions of global energy transition possibilities, see the recent debate between leading scholars in Volume 22 of the Energy Research & Social Science journal: Fouquet 2016, Kern & Rogge 2016, Grubler et al. 2016, Bromley 2016, Smil 2016, Sovacool & Geels 2016.

beyond the timing of adoption by different market segments. Geels & Schot (2007, p. 399) provide the multi-level perspective (MLP) to illustrate the transition pathway “from one socio-technical regime to another”, resulting from the timing and nature of the regime’s interactions with niche innovations and changing socio-technical landscapes.

At the community or household level, concepts surround how drivers of user decision-making and social acceptance shape technology adoption or behaviour over time, or how they are perhaps distorted through failures in the market (Howells et al. 2010, Kowsari & Zerriffi 2011). These involve theories from a range of disciplines that include; economics, social psychology, anthropology and sociology to explain energy behaviour based on concepts from the rational actor of microeconomic theory, to individual motivation and information, and the social context of individual actions (Lutzenhiser 1993, Wilson & Dowlatabadi 2007). Other concepts from the behavioural economics discipline are concerned with aspects of user-level decision-making to explain behavioural barriers to technology adoption; such as bounded rationality, salience issues, myopia, reference-point phenomena, and biased beliefs (Frederiks et al. 2015, Gerarden et al. 2015). There exist many other theories explaining the motivations for technology adoption; such as social acceptance theories which include the unified theory of acceptance and use of technology (Venkatesh et al. 2016), the theory of planned behaviour (Ajzen 1991), or theory of cognitive dissonance (Festinger 1957).

From the market perspective, diffusion of innovations thinking has been relied on by off-grid practitioners as part of their marketing strategies for off-grid products (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016). However, as mentioned in Chapter 3, some researchers have stressed the need for energy access practitioners to cease from a focus on hardware financing and private sector entrepreneurship, and also encourage the academic community to move away from its economics-engineering framing of the energy access issue (Ockwell & Byrne 2016). They have instead sought to combine elements of innovation studies and socio-technical transitions to present a new framework for addressing what they emphasise is the transformative change required for the sustainable adoption of low carbon energy technologies in developing countries (see Ockwell & Byrne 2016). This conceptual chapter takes a more micro-treatment, with a focus on energy service transitions from the perspective of a household.

The theories presented above surrounding user behaviour have predominantly been employed in developed country contexts for analysing and understanding energy demand (Kowsari & Zerriffi 2011). In developing countries, the theoretical underpinnings for understanding household energy transition (from traditional to modern) have thus far been based on the ‘energy ladder’ and ‘energy stacking’ theories (further explained in the sections that follow). However, recent work has been undertaken to expand the concepts used to analyse and explain the nature of energy demand, use, and change, in the context of the global

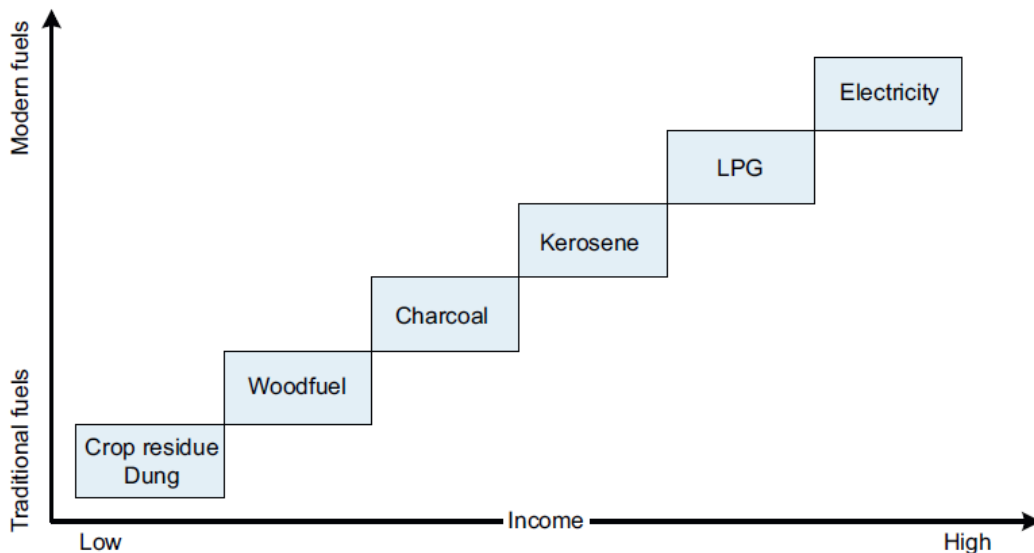
energy poor. What this chapter aims to do, is to further this progress with a conceptual framework that explains the sustainability of these transitions.

The rest of the chapter is set out as follows: Section 4.2 evaluates some of the long-standing and emerging concepts that are being used to explain household energy decision-making and transitions in a developing country context. Section 4.3 attempts to connect some of the explanations put forward by recent frameworks on the factors influencing household energy decision-making, to the evidence in literature on previously observed transitions. Section 4.4 presents a framework that conceptualises the energy transition of the energy poor and its sustainability, before Section 4.5 concludes the chapter.

## 4.2 Concepts of household energy transitions in developing countries

The earliest explanation of energy use patterns of the energy poor is found in the concept of the ‘energy ladder’; where households switch from traditional fuels to more modern fuels as their incomes (or economic status) increased (Leach 1992, Barnes et al. 1994, Elias & Victor 2005). Despite empirical evidence pointing to many limitations of the ‘energy ladder’ in explaining household fuel choice from as early as the late 80s (Hosier & Dowd 1987), the concept has been used widely for analysing and planning household energy services in developing countries (Reddy & Reddy 1994, ESMAP 2000, IEG 2008, IEA 2011*a*, Lepicard et al. 2017).

**Figure 4.1:** The energy ladder



Source: Kowsari & Zerriffi (2011)

The concept of the energy ladder is limited in its illustration of household energy be-

haviour in a number of ways. First, it assumes that the energy poor will behave in accordance with the neoclassical consumer, who is rational and seeks to maximise his/her utility. This is to say that households will move up the ladder to cleaner and more efficient fuels (such as those depicted in Figure 4.1) as soon as they are available and they can afford to do so (Kowsari & Zerriffi 2011). The result is a focus — for any attempts to affect the speed and extent to which households can move up the ladder — firmly on the monetary attributes of a household (income) and energy (prices), and the availability of modern fuels (Masera et al. 2000); despite evidence to suggest the presence of “a large number of other factors” (discussed later in this section) that are important to household fuel choice (Hosier & Dowd 1987, p. 347).

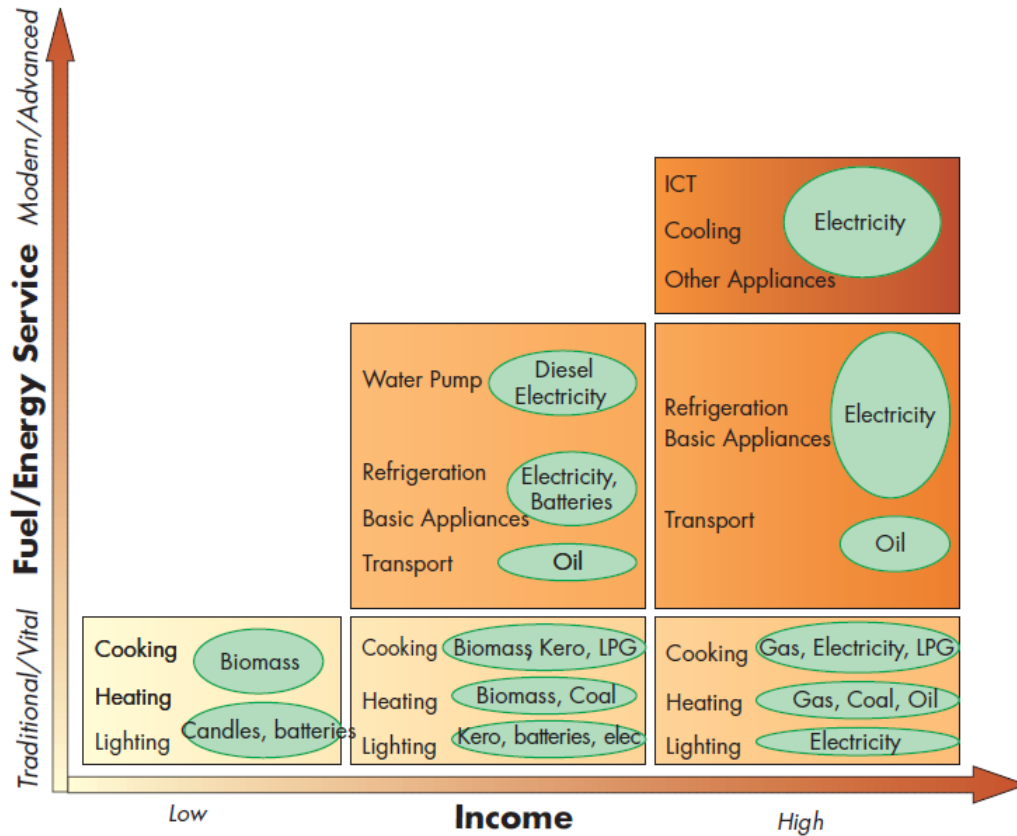
Secondly, the concept assumes a linear progression up the proverbial energy ladder, such that the adoption of each subsequent fuel corresponds to a displacement of the previous fuel used, in a ‘substitution’ (or switching) effect (Heltberg 2004). This can suggest that once a household adopts a modern fuel, then the poverty dimensions of the previous traditional fuel practices have automatically been forgone. However as discussed in Chapter 3, this is often not the case (see Section 3.5). Fuels along the ladder can, *inter alia*, be imperfect substitutes for each other due to the nature of tasks being undertaken by the energy poor, which are shaped by their socio-cultural characteristics (Davis 1998, Jiang & O’Neill 2004). This often means that households continue the use of a fuel lower down the energy ladder despite the adoption of a more modern fuel.

Finally, the energy ladder considers energy only in terms of the ‘fuel’ used by the household; neglecting the other considerations at play, as households seek to make use of energy to fulfil various tasks; such as the conversion technologies being used in conjunction with the energy carriers (fuel) (Kowsari & Zerriffi 2011). A focus on the energy carrier can give rise to excessive attention on the attributes of a fuel; which can distort the appraisal of a household’s relationship with energy.

Acknowledgement of the above limitations led to the development of the ‘energy stacking’ model as an alternative to explaining household energy behaviour; which gives explicit treatment to the second and third limitations discussed above (Masera et al. 2000, IEA 2002). The model considers dynamic changes to a portfolio of household energy services that accounts for changes in the fuels and technologies being used to meet existing service requirements, as well as new energy services made possible through the adoption of a facilitating fuel; such as the use of refrigeration services in accordance with the uptake of electricity (see Figure 4.2).

Similar to the energy ladder, the energy stacking model considers income to be a major determinant of household energy decision-making. In reality there are a plethora of factors specific to a household (economic, social, cultural) and its external conditions (physical en-

**Figure 4.2:** The energy stacking model



Source: IEA (2002)

*Note:* The IEA acknowledge that this is a static representation of what is a dynamic transition. For example, the transition does not follow a hierarchical path, as suggested by the figure, where the use of more modern energy for new services is done in accordance with the use of more modern energy for existing services, such as cooking and lighting; but rather modern fuels and technologies may be adopted for new services, such as refrigeration and ICT, while still relying on traditional energy only, for existing services.

vironment, policies, and markets) that interact in a complex manner to determine household energy behaviour (see Kowsari & Zerriffi 2011). In recent years various frameworks have been brought forward to address the limitations found in the energy ladder and further understanding of household energy decision-making. These are discussed in the subsection that follows.

#### 4.2.1 Frameworks on energy decision-making

Some frameworks have been developed to categorise the factors influencing the energy decision of the energy poor (beyond income) and explain interrelations in their influence. Kowsari & Zerriffi (2011) began by unpacking what is being influenced — energy use — into its relevant dimensions, the energy carrier (e.g. fuelwood), the conversion technology (e.g. ICS), and the energy service being provided by the former two (e.g. cooking), to make up what they term the “Household Energy System”. This emphasises the importance of considering how the factors of the decision environment influence each dimension of the

system, as well as the interrelations between the dimensions to provide certain energy usage outcomes.

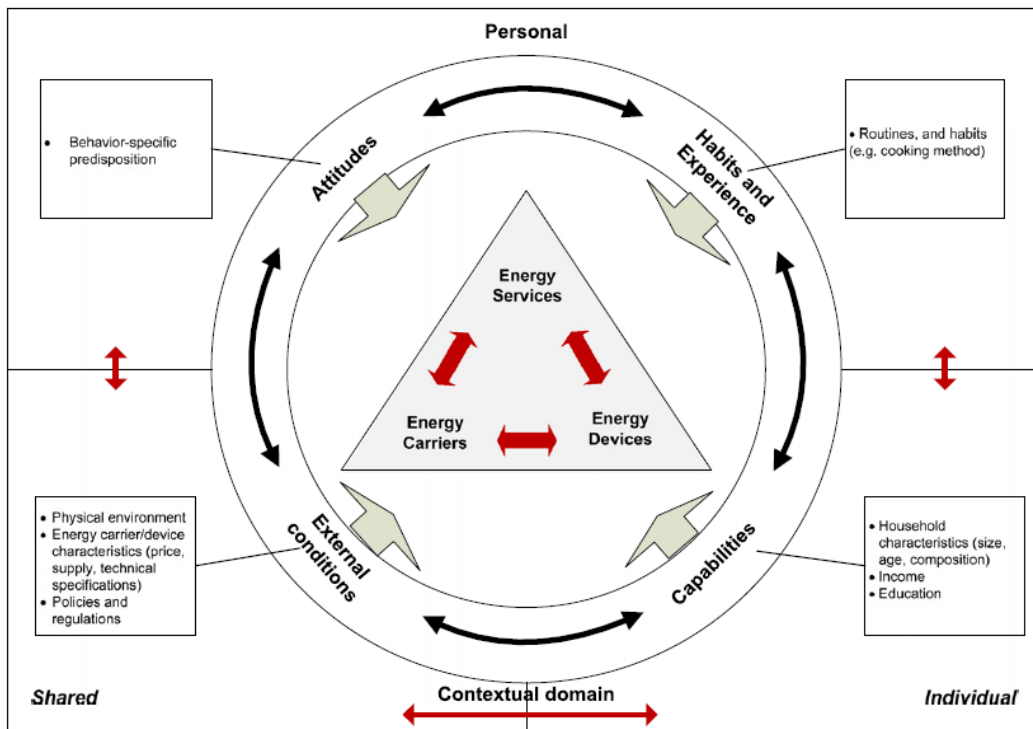
They draw on Stern’s (2000) use of the Value–Beliefs–Norms (VBN) theory — from the social and environmental psychology discipline — which forms part of an integrated model explaining pro-environmental behaviour with regards to residential energy efficiency. The VBN theory considers the attitudes of an individual or a household towards environmentally significant behaviour to be explained by the direct effects of a causal chain beginning with a person’s relatively stable elements of personality (values: e.g. altruism), through to their specific beliefs about the consequences of human-environmental relations (beliefs: e.g. a perceived ability to reduce threat), on to their personal responsibility for corrective action (norms: e.g. sense of obligation to take pro-environmental action). This attitudinal indicator, Stern posits, gives a sense of a decision-maker’s predisposition for behaviour change. Kowsari & Zerriffi’s adaptation of this mode of thinking on energy efficiency decision-making, to suggest an energy poor household’s predisposition to behaviour change from traditional energy services to modern energy services is appropriate; as both energy efficient and modern energy decisions, encompass similar behavioural considerations (e.g. capital investment, practical use adjustments, activity curtailments).

Just as Stern warns; attitudes describe intent, and intent does not necessarily mean action. This is also true for behavioural change between traditional energy services and modern energy services. An individual can be predisposed to adopting modern fuels and/or technologies to perform current services differently or to make use of new services; but it does not mean they will adopt and use it as intended. This is a particular limitation of the stated preference method that often features in examinations of consumer WTP for modern energy services (see Taale & Kyeremeh 2016, for a review of these examinations). Therefore, the second part of Stern’s integrated model — also incorporated in Kowsari & Zerriffi’s — accounts for the other factors, besides intent, that affect behaviour. It relies on the “ABC theory”, which caters to attitudinal (A) and contextual (C) impact on behaviour (B) by implying that an individual’s resulting behaviour depends on the distribution (positive or negative) of their attitude and external conditions relative to each other (Guagnano et al. 1995). The model works bi-directionally in that, the influence of attitudes on behaviour are strongest when external conditions are neutral; but when these conditions are strongly positive or negative, the attitude-behaviour association weakens as the conditions compel or prohibit the behaviour in question (Guagnano et al. 1995, Stern 2000).

Stern expands on this theory to suggest four causal variables that explain environmentally significant behaviour: attitudes, habits and experience, capabilities, and external conditions. The former two are specific to the particular behaviour in question (personal domain), while the latter two form the individual and shared contexts in which a person’s

attitudes and habits exist (contextual domain). Kowsari & Zerriffi adopt these groupings; and the simple premise of adopting these categories of factors influencing environmentally significant behaviour or energy service decision-making, is that the different groups and variables influence each other in different ways to have a resulting effect on behaviour (see Figure 4.3). A person's predisposition to adopt a new cookstove (attitudes) can be realised depending on factors such as their income (capabilities) or by financial incentives (external conditions). At the same time scarcity of fuelwood (external condition) can make existing cooking habits unsustainable (habits and experience) necessitating that an individual considers their attitudes towards cooking; or as Kowsari & Zerriffi allude, their attitude towards the cooking service, the cooking technology, and/or the use of fuelwood and other cooking energy carriers.

**Figure 4.3:** The three dimensional energy profile



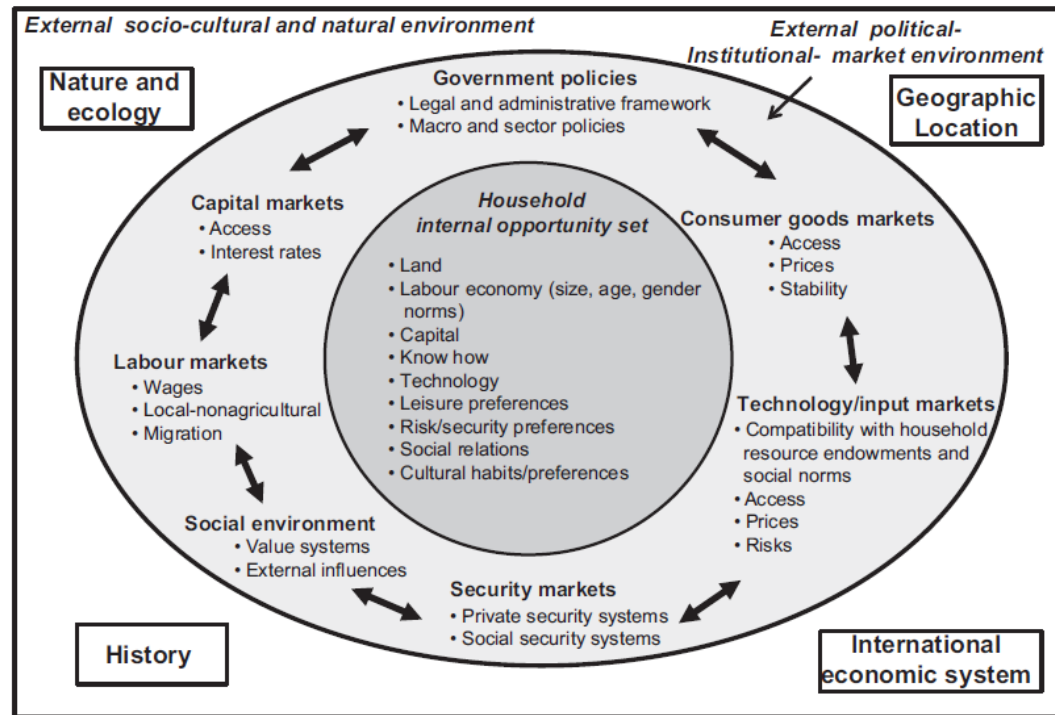
Source: Kowsari & Zerriffi (2011)

Van Der Kroon et al. (2013) developed a framework similar to Kowsari & Zerriffi's to illustrate the "complex and interactive web of factors" that influence a household's energy behaviour. Their framework gives greater treatment to the macro factors influencing household decisions; as they separate factors pertaining to the external forces that have shaped societal attitudes and culture, such as the capabilities of a country's or region's natural environment, its role within global affairs and its history (the *external and socio-cultural environment*), from the current changeable political, institutional and market environment



(the *external political-institutional-market environment*) (see Figure 4.4).

**Figure 4.4:** Conceptual framework explaining household energy choices



Source: Van Der Kroon et al. (2013)

The above two categories expand on what Kowsari & Zerriffi highlighted as the ‘external conditions’ of the contextual domain, and have been unpacked by Van Der Kroon et al. to differentiate between society’s long-standing natural environment and idiosyncrasies (predisposed societal attitudes, habits and experiences, norms), and capabilities (political–institutional–market environment); similar to how the former authors make the differentiation for the individual (see Figure 4.3). Van Der Kroon et al. combine what Kowsari & Zerriffi categorise as the personal and individual context dimensions of a household to denote a “household’s opportunity set”; which they say, “determines the capacity a household has to reduce its vulnerability and restricts or broadens their window of opportunity” in terms of their livelihood (Van Der Kroon et al. 2013, p. 507).

Placing this category at the centre of the decision environment asserts what both frameworks aim to acknowledge to be important when considering human behaviour — that individual actions should be considered within their social contexts (Lutzenhiser 1993). Yet at the time of their paper, Van Der Kroon et al. (2013) highlight that not enough studies consider the household energy behaviour beyond the lens of the household opportunity set. Some studies that have been cognisant of the context in which households make their decisions have provided evidence of interactions between the external conditions of a household

and its individual characteristics, that serve to influence change in energy behaviour (Lay et al. 2013, Link et al. 2012, Sehjpai et al. 2014, Wang et al. 2012).

Lay et al. (2013) found evidence to support the argument that the social environment in which a household is situated has an effect on its personal attributes that lead to an increased likelihood of adopting modern energy fuels. Based on their regression model of representative survey data in Kenya, they test the determinants of lighting fuel choice and find that “the largest average marginal effect on the use of solar can be found for the prevalence of SHS in the district, suggesting that the accessibility and local knowledge about SHS are of large importance for the decision to install SHS” (ibid., p. 356).

Examining the extent to which the social organization of daily life explains the transition from fuelwood to alternative fuels in rural agrarian Nepal, Link et al. (2012) find that the creation and increased use of non-family organizations — for example through employment, banking, markets, schooling, health care, transportation, and leisure — decreases the degree with which daily activities are organised within the family, and encourages less reliance on fuelwood and greater use of alternative fuels. Conventional thinking on energy access is that the provision of modern energy brings about benefits associated with the above non-family organisations (health, education, productivity, information etc. — see Chapter 3. The suggestion here is that engaging with the organizations that bring about such benefits, facilitates the use of modern energy.

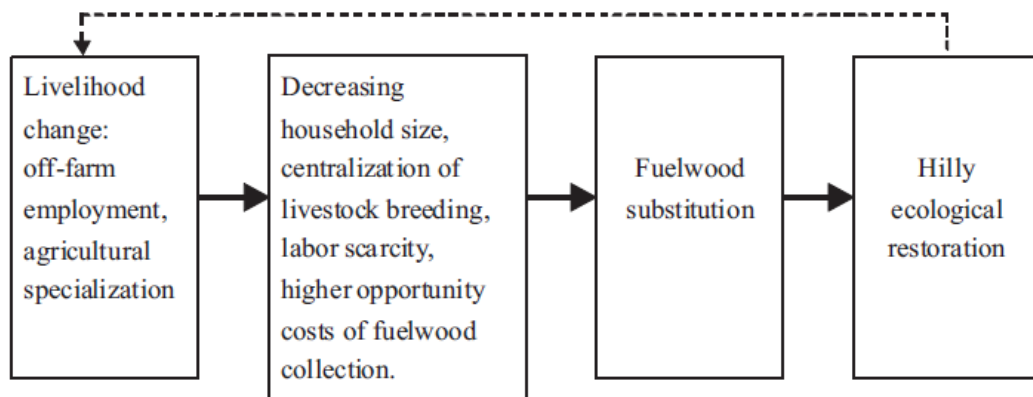
This is an important difference, as it feeds into the question of what should be the focus of interventions, not only from an equitable point of view, but as a means of achieving sustainable adoption of modern energy services. For example, in the formative view it is expected that modern energy lighting will aid children studying at night time and when provided at school, can support educational activities. However, Link et al. theorise an explanation that suggests, that if children are at school, there is less time to collect fuelwood and therefore encourages the household to switch to fuels that require less collection effort. The approach used by Link et al. to test this truth — a logistic regression model of multilevel longitudinal data to test that the odds of using an alternative fuel is explained by access to a non-family organisation — leaves open the possibility of correlation as opposed to causation. Nevertheless, it shows that where there is decreasing reliance on fuelwood, there also exist critical infrastructure and services.

Also relying on a regression model to estimate the probability of using a modern energy fuel as a result of factors other than income, Sehjpai et al. (2014, p. 1) support the above claims as they observe that “as women move towards formal employment, the odds of choosing cleaner fuels increase significantly”.

From a qualitative angle, Wang et al. (2012) find evidence to show that fuelwood substitution is inextricably linked with changes in the livelihood of rural households. Embracing

sociological explanations of household decision-making, they use a case in rural China as an example to conceptualise that a change towards large-scale commercial farming and thus greater specialization in agricultural production practices affects the livelihoods of rural households, such that it brings about the substitution of fuelwood with alternative fuels. This then results in ecological restoration, with a positive feedback on productivity and agricultural specialization (see Figure 4.5). Among a few explanations they find, that lead to reduced pressure on ecosystem resources, they observe that an increase in off-farm employment necessitated that households change their pattern of energy consumption due to the higher opportunity costs of fuelwood collection.

**Figure 4.5:** Conceptual framework of rural livelihood change and fuelwood substitution



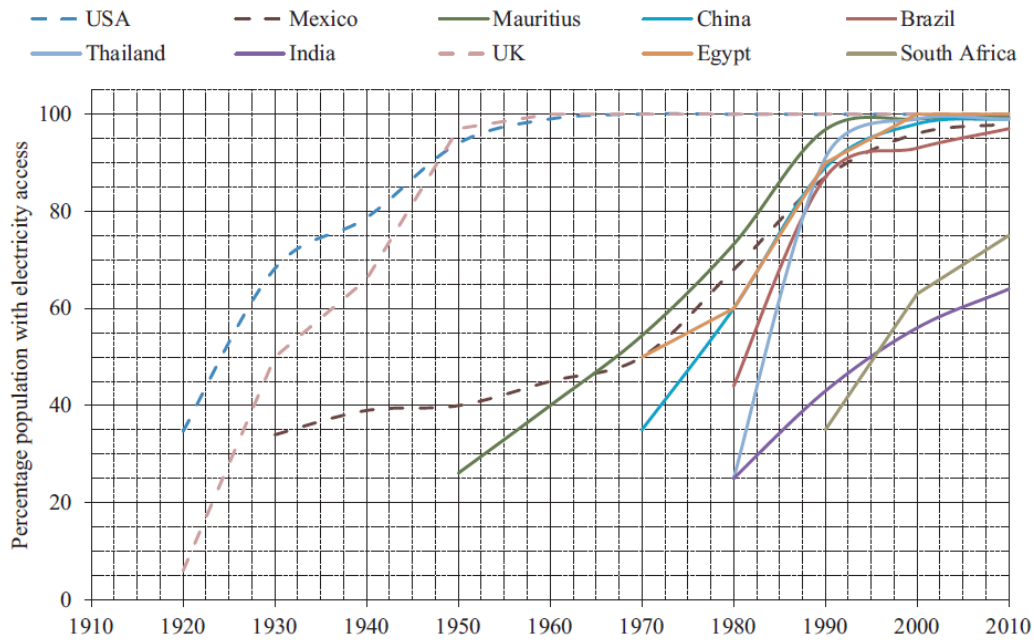
Source: Wang et al. (2012)

The next section will take a brief look at country experiences documented in literature that illustrate how the personal attitudes, norms, values, habits and capabilities of a household, and its internal and external contextual factors interact and perhaps change over time, to affect household energy decision-making.

### 4.3 Conceptual lessons from household energy transitions

Over the past century, numerous countries have experienced household transitions to modern energy services in varying degrees and under varied contextual situations; some of which were highlighted in Chapter 3. Over a period of about 30 years from the 1920s, the U.S. made substantial progress electrifying its unserved populations. This was preceded by an increasing shift away from fuelwood dependence for heating, replaced by coal, later oil, and then natural gas and electricity (O'Connor 2010). Since then, countries with vastly different contexts, such as Brazil, Thailand, Egypt, China, Mexico and others, transitioned almost 100 % of their households to electricity (see Figure 4.6).

**Figure 4.6:** Historical experience with household electrification in select countries



Source: GEA (2012)

Taking a look at the transitions experienced in countries such as these can inform some of the connections suggested by frameworks looked at in Section 4.2. The contexts of some of these countries vary widely from the context of countries where the energy poor reside today; such as in relative levels of development, global and national development concerns, and the technological landscape. Therefore, this section does not suggest that there are norms to be followed, but rather seeks to extract some key messages about the interactions and influences within the decision environment of households, the forces that have been observed to drive them, and their impacts on household behaviour. As Kern & Rogge (2016, p. 14) acknowledge; “history is important in order to understand the dynamics of transitions”.

### 4.3.1 Changing capabilities and personal attitudes

In Section 4.2 it was highlighted that income, though important, was not the only determinant of household energy behaviour. Therefore, a household’s perception of the cost of using energy of a certain nature or in a particular manner is not limited to its monetary characteristics, but dependent on the extent to which it presents or restricts their opportunity to meet their livelihood needs; needs which can change independent of and as a result of energy use. Innovative energy services can provide a household with an option that suits their livelihood strategy; as seen with some recent technological developments and financing mechanisms discussed in Chapter 3. At the same time, changes to a household’s livelihood

can change the requirements and thus opportunities needed to meet it; therefore, changing the cost of using or not using an energy service, energy carrier, or conversion technology. Previous experience suggests that sustainable household transitions involve favourable shifts in the conditions of the two. The latter force however, more specific to the households and communities, has received less practical attention in energy access activities today.

Around the turn of the twentieth century structural adjustments to the U.S. economy led to changes in the way rural households consumed fuelwood. Up until then, farm households in the U.S. used fuelwood extensively for heating and cooking (Fernandes et al. 2007). The arduous process of gathering the resource could be justified since it integrated well with farm activities (MacFayden 2010). However developments in specialized farming operations decreased the demand for manual labour and people sought growing opportunities for off-farm employment in neighbouring rural and metropolitan regions (Dimitri et al. 2005). The opportunity cost of fuelwood collection to a household increased as a result, setting the platform for a favourable transition to available alternative fuels. As mentioned in Section 4.2.1: Wang et al. (2012) highlighted a similar process to have taken place in rural Southeast China; Sehjpal et al. (2014) made similar observations from a study of diverse villages in Central India; and Link et al. (2012) found evidence to suggest the same in South-Central Nepal. Manning & Taylor (2014) also came to the same conclusion from observations in rural Mexico.

This pattern of change, and the impact it had on energy transitions in China, led Han et al. (2014, p. 235) to argue that “urbanization is a key part of addressing energy poverty over the long run”. People’s daily habits differ considerably when working on or off a farm. When alternative forms of energy are available, this change in habits influences a household’s attitude to fuelwood collection and its impact on their livelihood values and needs. The influence of habits on household energy behaviour were also in the company of other influential characteristics and changes within the decision environment. In the US, off-farm work increased household incomes therefore increasing the ability for households to engage with alternative energy services (Dimitri et al. 2005).

The above experiences show how the personal capabilities and attitudes of households, or as Van Der Kroon et al. (2013) put it, their opportunity set — from changes in income, to changes in daily activities — influenced their energy behaviour.

### **4.3.2 Changing local context**

Much of the rural energy poor in developing countries today can be classified as smallholder farmers who, as a major part of their strategy to sustain their livelihoods, own or lease land for subsistence and low productivity commercial purposes (Altieri & Koohafkan 2008). This was the state of farming in some developed nations of today, around the turn of the

twentieth century; e.g. Germany (Pierenkemper & Tilly 2004). It has been highlighted that the German government’s agriculture sector activities in the early 1900s formalised the operations of cooperatives and addressed liability concerns, aiding their sources of information, their knowledge, and practices, and paving the way for greater commercial lending to the sector (Axelrad et al. 2014). This increase in the capabilities of communal structures and organizations has been noted as instrumental to the success of rural electrification in the early 1900s (Sanchez & Tozicka 2013). The above development, in which existing modes of coordination and production in agriculture and local development were used to facilitate modern energy production, delivery and thus transition, were also true in the U.S. and China (Sanchez & Tozicka 2013, Han et al. 2014).

More recently, the lauded experience of Vietnam’s electrification achievements, used a strategy that initially began with raising the capabilities of local households (Gencer et al. 2011). The initial electrification strategy in the 1970s prioritised the “rice-producing areas of the Red River Delta in the north and the Mekong River Delta in the south”; facilitating the country’s position within the top five exporters of rice globally (ADB 2011, p. 1). In the 80s, the strategy was to provide electricity for agriculture and to industries across all areas of the country to bring about economic development at the local level (ADB 2011). It was not until the 1990s before the government sought electricity to all households, but also meant that households could afford the service due to years of local productivity growth, jobs, and growing experience with electricity ADB (2011), Gencer et al. (2011).

Infrastructures, such as transportation networks, are considered important for rural development (Cook 2011), and have played crucial roles in supporting previous household energy transitions. They facilitate market access for rural products, while also making it attractive for non-farm industries to be situated in rural areas (Jacoby 2000). For household energy behaviour, such support systems have important implications on transitions. As touched on in Chapter 3, solar irradiation is a resource typically available to remote communities, yet if the systems used to convert sunlight to useful energy are reliant on external production systems — such as in a different country — this increases the risk of an unsuitable or unstable technological market, which can depress uptake or continuity of use by households.<sup>2</sup> Indeed, the success of electrification efforts in the U.S. and China, which included overcoming technical issues, have been attributed in part to the presence of local manufacturing capacity within the respective countries (Beall 1940, Bhattacharyya & Ohiare 2012, Zhang & Gallagher 2016).

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<sup>2</sup>See Khandker et al. (2014) for an example of such influences with the SHS experience in Bangladesh.

### 4.3.3 Polycentrism

The local context concerns discussed above are influenced by a number of factors, from security to labour and to capital markets; described by Van Der Kroon et al. as the political–institutional–market environment (see Figure 4.4). It suggests that the drivers of household energy behaviour, and changes to this behaviour, involve the efforts of multiple actors; or as indicated in Chapter 3, Sovacool’s (2014*a*) suggestion of polycentrism. This polycentric mode of action was observed to have been a feature of Vietnam’s electrification approach.

All tiers of Vietnam’s government (local, provincial, national) were involved in financing transmission and distribution networks; local consumers were involved in establishing community distribution networks either through personal finance or labour commitments; the private sector developed electricity generation infrastructure; commercial lenders extended loans to private and public actors; the national development bank provided low interest loans to local cooperatives; multilateral and bilateral partnerships supported the development of power infrastructure; local governments coordinated development synergies in the form of schools, clinics, roads, and staff; the state utility was used to channel investment and technical support; the electric power university trained technical staff; farmers invested in value-adding agricultural processes; businesses setup food processing factories that ensured the farmer at the beginning of the value chain had a market for his/her growing business — all these, influenced the generation, extension, connection, affordability, and use of electricity by previously unconnected users (ADB 2011, Gencer et al. 2011).

The activities listed above only provide a snapshot of the actions and actors that influence the external conditions of the household decision environment, and the interactions that shape energy behaviour. It is often cited that for effective coordination of an energy access programme right along the value chain to bring about wide-ranging and lasting success, a key requirement is “political will” (Niez 2010, Ahn & Gaczyk 2012, GEA 2012, Brew-Hammond et al. 2014). What exactly constitutes political will, and the scope of its influence on energy access activities is not always clear.

For example, a definition of political will that centres on the determination of the highest individual authority in the land (such as a king/queen, prime minister, or president), assumes a number of prerequisites to concerted action including, inter alia; the political and administrative capacity to achieve the desired outcome, sufficient material resources, the ability of the individual to effectively project his/her will to the effective undertaking of others, and limited or ineffective opposition to the purpose of the individual’s will (Manor et al. 2004). These considerations cut across the powers and interests of multiple actors within the political, economic, social, and institutional spheres. The extent to which the presence of political will can therefore be translated into concerted action is therefore partly down to the existence of consensus amongst various communities of interests, or such that

opposing interests are subdued, towards achieving political economic consistency on a stated goal.

Sebitosi & Pillay (2005) contrast the experiences of the U.S. and Kenya to suggest why specifically targeted legislation led to rural electrification and rural community development in one instance (the U.S.), and underwhelming results in the other (Kenya); listing possible explanations in the forms of corruption, mismanagement, government interference, and misleading objectives. As with many major projects, the U.S.'s rural electrification journey was fraught with challenges of its own (see Barnes 1988), but it was able to take the actions needed to overcome them. This can be put down to an alignment of the interest of multiple actors at various levels to the will of the incumbent president at the time — President Roosevelt — which sustained the political economic consistency required to achieve the stated national goal (Pellegrini & Tasciotti 2012).

For instance, similar to Vietnam it was observed that in the U.S., rural electrification was seen as key to the welfare of U.S. Agriculture: the administration were willing to make necessary resources available to overcome challenges faced; the rural electrification administration (REA) was adequately staffed with personnel capable of providing cooperatives with expert support; resources were allocated to facilitate the involvement of specialists in supportive sectors to aid growth of rural markets; universities were involved, and so were necessary ministries such as the agricultural ministries (Beall 1940).

China's energy transition, also situated within the broader context of development, garnered action at multiple levels: with central programme planning and support, the implementation of energy solutions could be decentralized because villages and townships were willing to take charge of hydropower development and grid construction; the government cut VAT to support small hydropower and provided fiscal allocations to ensure funding for engineering projects, technical training, and information services (Bhattacharyya & Ohiare 2012, Han et al. 2014). Similar polycentrism was observed in successful cases of adoption and sustained use of improved cookstoves in China (see Shen et al. 2015).

Polycentrism can inspire support for, and implementation of bold, ambitious policies; policies that may otherwise face stern opposition. If the decisions of politicians are subject to constraints and pressures from interested groups, then the latter must be strong enough or appropriately organised so as to wield influence (Manor et al. 2004). In the case of energy poverty, this suggests the mobilisation and organisation of an important interest group into a political force — the energy poor. Something which is seldom found in the countries where they reside (Brook & Smith 2000).

The political economic consistency that emerges from polycentrism provides a platform for ambitious activities, as stakeholders are more invested in the transformation process, and possess greater trust in the activities and decision-making of the various parties. This



can affect activities to provide access to energy services, but also the decision to make the transition from the point of view of a household. In the U.S. experience, it was observed that effective and consistent administration of funds via the REA, alongside industrial activity to provide tailored technology for electricity and agriculture, shaped the confidence of cooperatives and farmers in pursuing ambitious grid extension activities and investing in productive farming and household electrical equipment (Carmody 1939, Beall 1940). In Vietnam, the national commitment to training technical staff through the electric power university ensured cooperatives had access to skilled personnel for operation and maintenance activities; which represented an important aspect of their approach to building customer relations (Gencer et al. 2011).

Experiences in some developing countries that have involved false promises or short-lived infrastructure for the purpose of political expediency, is exactly the kind of inconsistency that leads to a breakdown in trust and unfavourable interactions within the household decision environment; thus, hindering transitions. In an extreme example, Sebitosi & Pillay (2005) presented the result of such a case in Malaysia:

“During polling campaigns, politicians reportedly, went as far as delivering electric power poles to villages, apparently as proof of a *fait accompli* but would subsequently recover them after the polling! In apparently retaliation for a previous experience, the villagers would, collect the poles, whenever such a ploy would be repeated, and use them as firewood and building material. Sadly this would include occasions when the intentions to electrify were genuine. (ibid., p. 2047)

The external environment in which households undertake energy service decisions is largely shaped by the activities of the government, both energy-related and non-energy related, as indicated in Van Der Kroon et al.’s (2013) framework (external political-institutional-market environment in Figure 4.4). If, as is the case in many energy access projects, government leadership is absent, then modern energy activities risk being out of tune with other government-influenced factors that impact the decision environment. This illustrates why political will is often cited as a necessary component to successful energy access projects.

Nevertheless, as the frameworks discussed in Section 4.2.1 show, the external environment is just one of the dimensions impacting household energy decision-making, and the examples presented here from historical transitions only provide a limited view on the considerations being had socially and personally when a household decides to behave in a particular way. The next section takes a look at some concepts put forward to explain observed household energy behaviour in developing countries, and presents a framework to explain the sustainability of household energy transitions.

## 4.4 A framework for understanding the sustainability of household energy transitions

As mentioned in Chapter 3, it has been widely observed that energy stacking is the likely behaviour as modern energy services are adopted by the energy poor (Masera et al. 2000, Baiyegunhi & Hassan 2014, Guta 2014, van der Kroon et al. 2014, Lee et al. 2015); this specifically highlighting the use of multiple fuel and technology combinations for the same energy service (e.g. fuelwood and LPG for cooking). However, the energy consumption patterns of households in other contexts of developing countries, or indeed in other regions of the world suggest that this need not be exclusive. It has been implied that the use of multiple fuels is a transitional intermediary step along the transition process of the energy ladder, before the final transition behaviour where substitution is exhibited (Ahmad & Puppim De Oliveira 2015). But when present, the period of time this transitional intermediary step covers is unknown, and can fail to progress to the substitution stage.

Van Der Kroon et al. (2013, p. 512) conclude that “energy stacking behaviour can be seen as a livelihood strategy through which households cope with irregular income flows, protect themselves from unstable markets and hold on to their cultural practices, while benefiting to some extent from modern fuels”. Similarly, Treiber et al. (2015, p. 60) explain that where there exist multiple options for meeting an energy service, households are driven “to possess more than one fuel or stove due to energy security reasons” and that the “situation and context of the task” has an effect on the fuel and device being used.

The above point to a household’s concern for its energy (service) security as it pertains to its livelihood practices (Herington & Malakar 2016). This suggests that energy stacking is an act households take to secure, for example: their ability to cook against fuel and/or stove access constraints (external conditions variable); their energy service from affordability risks due to potential variability in their income (individual capability variable); their habitual meal preparation practices (habits and experiences variable); to secure their ability to cook valued foods (values and norms variable). This means, that for a given energy service (e.g. cooking), the provision of energy in a way that secures the above security concerns could decrease the practice of energy stacking; or perhaps, favourable changes in the nature of these security concerns will increase the ability for an energy service to secure them and thereby reduce the need for stacking. An example for the former case can perhaps be a cookstove that aids the cooking of preferred foods as desired by the user. A possible example for the latter case is greater stability in income that will decrease affordability concerns.

However, if household energy behaviour results from complex interrelationships between the personal values, norms, beliefs, habits and capabilities of the household, and the environment in which it is situated as constructed by its natural, social, and cultural environment,

as well as the political, institutional, and technological landscape, this presents a very complex set of possible interactions that shape livelihoods and the attempts to secure them. Empirical evidence has showcased the relevance of these interactions. But how can the nature of these interactions be explained, and the behaviours and transitions they produce? An understanding of this can inform the conditions needed for interactions that will lead to sustainable substitution of traditional energy services over time.

Using their three-dimensional energy profile — in which household energy use is broken down into an energy service demand, the energy carrier, and the conversion technology used to meet that energy service — Kowsari & Zerriffi (2011, p. 7515) argue that household energy transitions should be considered as shifts that take place along a three dimensional path “due to changes that occur in any of the three dimensions”. In their model, the different interactions that impact household energy decision-making can lead to changes in each of the three dimensions to provide a cumulative effect observed in the transition.

There are a number of questions that follow on from this: what explains the different types of effects on each of the three dimensions? what effects, if any, do changes in one dimension have on another? how can this be used to explain transitions along the range of household energy service demands and the various energy carriers and energy conversion technologies? what can answers to the above questions explain about observations of energy stacking or in some cases substitution?

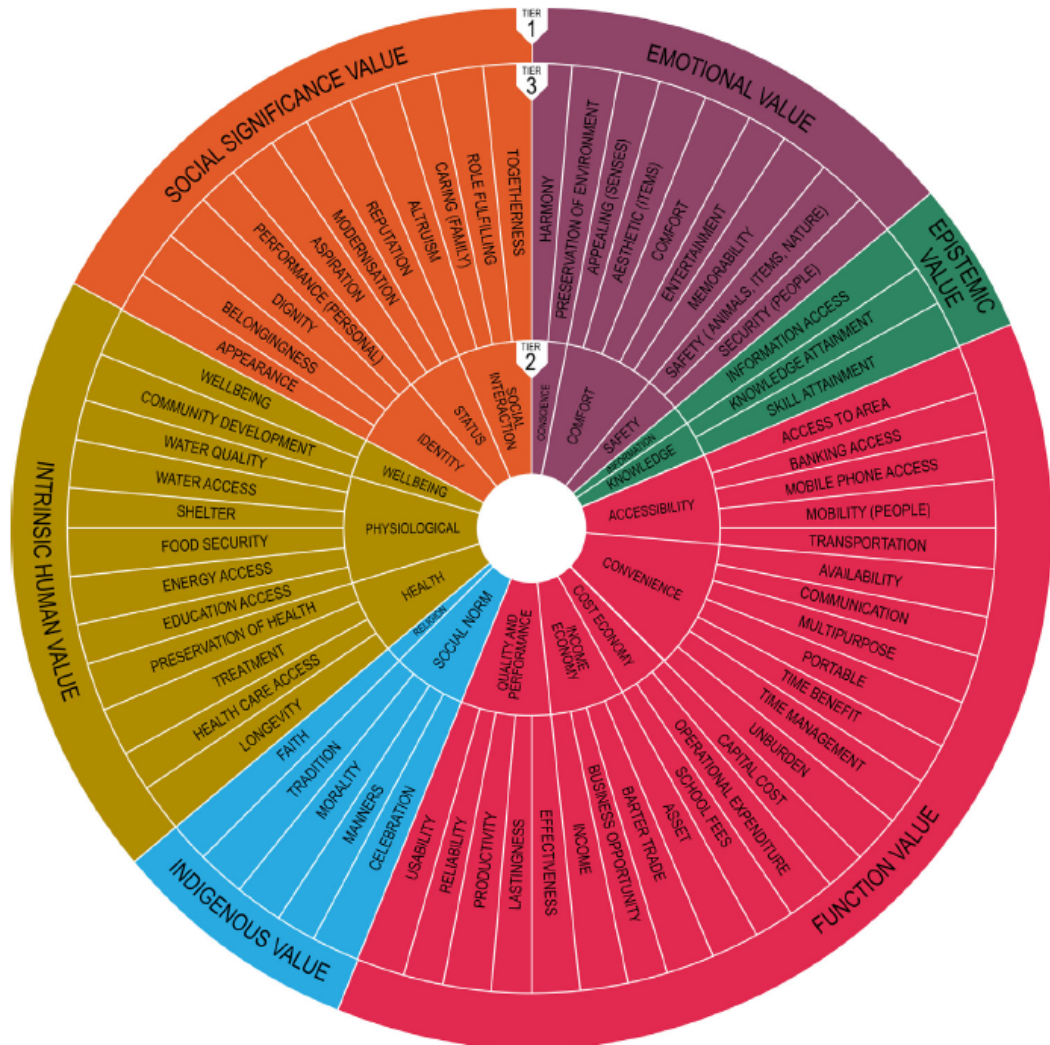
To understand this, it is useful to take a step back from the full spectrum of factors driving household energy behaviour, and consider decision-making as a practical element of living life, day to day, week to week, month to month, and year to year. Because it is unrealistic to suggest that households logically, and consciously, consider the plethora of complex interactions at play when making their numerous decisions regarding energy use and their livelihoods in general. At the end of the day — as behavioural economists would stress — some decisions will be based on reasoning and others will be intuitive (Kahneman 2003).

One way of tackling the issue is by considering energy consumption at its foundational purpose. It is now widely accepted that energy demand needs to be viewed as a social construct, for reasons clearly stated by Wilhite et al. (2000, p. 118); that “People do not consume energy. They consume the services it makes possible”. Therefore, key to understanding energy demand, is an understanding of the demand for the services made possible by the provision of energy. Taking a bath is a service that can be made possible by the energy provided to pump and perhaps in some cases heat water. Then the demand for its service can be associated, *inter alia*, with the desire for hygiene. Understanding why a group of people in a household desire hygiene makes it possible to: understand how and why they bathe and potential thresholds that exist for frequency to shower, assess the importance of

available water heating to them or pumped water, and understand how the forces within the decision environment would interact to produce a demand for the related energy carriers and conversion technologies.

Hirmer & Guthrie (2016) built on a user-value-perceived framework, originally developed by Hirmer & Cruickshank (2014*b*), to present a framework — for analysing user-value of rural electrification — that is cognisant of the above issues. They develop a “user-perceived-value wheel” which can be used to understand why a user considers something to be important, such as an electricity service; therefore, indicating the drivers that lead to user acceptance, and thus sustainability of an initiative. They propose six pillars that pertain to user-value; functional, social significance, epistemic, emotional, intrinsic human, and indigenous values. In the case of electricity, this captures the essence of service to a user beyond the physical-technical aspects of energy use (functional value) to include aspects such as the value found from an increase in perceived social status resulting from owning or receiving something considered to be prestigious (social significance value) (see Figure 4.7).

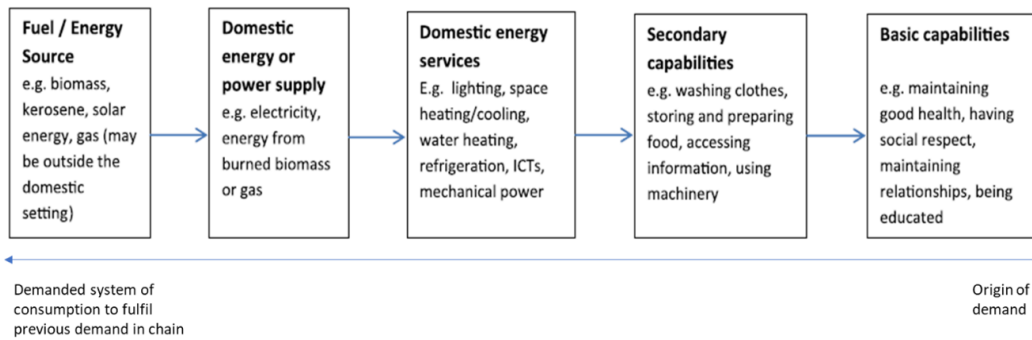
**Figure 4.7:** User-Perceived Value Wheel



Source: Hirmer & Guthrie (2016)

When attempting to present a suitable definition of energy poverty, Day et al. (2016, p. 259) draw on Amartya Sen and Martha Nussbaum's capability theory to conceptualise the relationship between demanded energy stored in its natural resource, through to the basic capabilities (fundamental objectives) being fulfilled as transferred energy is used — the latter of which they contend, is “an individual or household's ultimate concern” (see note in Figure 4.8 for ‘capabilities’ definition).

**Figure 4.8:** The relationship between energy, services and outcomes



Source: Adapted from Day et al. (2016)

*Note:* The term *capability* can be defined as a person's freedom to achieve well-being through functioning; *functionings* constituting things, such as being in good health or being adequately nourished, that an individual has been opportuned to be or do (Sen 1992). In this framework, the abstract concept of a capability has been expanded to categorise 'basic capabilities' as the general functionings that are most fundamental to human well-being (e.g. life, social relations, knowledge), and 'secondary capabilities' that capture the mechanisms by which basic capabilities are realised (Smith & Seward 2009).

It can be argued then, that the demand for an aspect within each previous stage along the chain (going from left to right) in Figure 4.8 is dependent on, but not limited to, the demand for a related aspect or multiple aspects within the subsequent stage. For example; as part of maintaining good health (basic capability), households eat food they have prepared (secondary capability), which was achieved through cooking (domestic energy service), by burning biomass with a stove (fuel source/domestic energy). Each previous activity in the chain in Figure 4.8 would not be in demand, if there was no desire to maintain good health. Choice therefore emerges when considering the different options that exist at each level above the basic capabilities stage that can be demanded in a bid to maintain good health, and to what extent each option may be in competition, mutually beneficial, or independent of each other. Further complexity also emerges when demands at each stage can be used to fulfil multiple demands at the next stage (e.g. food is eaten not just for good health).

Based on this, energy consumption at its source is dependent on the existence of a demand to meet a basic capability (or need), and the systems adopted to meet this fundamental demand are shaped by the demand for options available at each stage of the chain in Figure 4.8. However when thinking about decision-making, the social-energy interaction is more complex than Figure 4.8 would suggest. Hirmer & Guthrie's (2016) 'social significance value' is one example of this. A household decision-maker may decide to purchase a modern energy technology to be perceived as having status (basic capability) within society. This basic capability is governed by the ownership of an energy technology, and is less concerned with the transfer of energy from fuel source to end-use, but nevertheless determines that the energy technology becomes a demand option to be used as a domestic energy service to meet another basic capability.

Furthermore; the above frameworks give a comprehensive treatment to some of the innate desires of an individual or household and how they drive the perception of value in a fuel, technology or service, and thus demand. From the perspective of transitions however, it is worth remembering that a household's use of energy services does not operate within a vacuum. There are many different services and demand for services (not necessarily specific to energy) linked to the basic capabilities of peoples, which may also have the ability to change.

Economic concepts of induced and autonomous consumption would suggest that not all basic capabilities are equal in importance to an individual, and can vary between individuals and households.<sup>3</sup> This is the same for other stages of the chain, such as the secondary capabilities and domestic energy services, etc., because of the level of importance of the basic capabilities they are connected to, and also independent of them. The latter case (difference of importance independent of basic capability connection) can be exemplified by two competing energy services to fulfil a particular secondary capability; or two different types of food to fulfil a particular basic capability.

If the basic capabilities are linked to fundamental human values, and thus ubiquitous, then differences in the desire to fulfil them between one individual to the next are only dependent on the extent to which each basic capability is under recognition at any point in time (Maslow 1943). So, all humans get hungry and need to eat, but not all at the same time. Whereas for secondary capabilities and stages above it, the existence and importance of a demand option is dependent on a household's context (Walker et al. 2016); where, the existence of a secondary capability can be determined by the production of new technology or service with new functions, and its importance influenced by the extent to which the technology or service leads to lock-in and becomes synonymous with everyday life (Geels & Schot 2007). For example, in the case of mobile phones or personal computers; where for the former, the secondary capability is *instant* long-distance communication.

Taking a sustainable livelihoods perspective; individuals or households seek to enhance and ensure their means of living over the long term (sustainable), through the direct or indirect use of their physical, natural, financial, social, and human resources/assets (livelihood capitals) (Cherni & Hill 2009).<sup>4</sup> Here, the *physical capital* refers to the basic infrastructure of a household's surrounding environment, such as roads and buildings; the *natural capital* captures the natural resource stocks and environment of a household including ecology, cli-

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<sup>3</sup>According to the Keynesian model on consumption, autonomous consumption is defined as expenditures independent of disposable income, that is, the consumption of necessities; whereas induced consumption is influenced by changes in disposable income (Arnold 2014).

<sup>4</sup>Sustainable livelihoods thinking has become a core principle of international development, particularly with the UK's Department for International Development (DfID); who adopted the Sustainable Livelihoods Framework (SLF) to — amongst others — facilitate a people-centred approach to development activity (see DfID 2001). This work draws on the five capitals of SLF, as outlined in the main text, to represent the scope of assets or resources by which a household seeks to sustain or enhance their way of life.

mate and anthropogenic pollution; the *financial capital* refers to the cash, credit, savings and other economic assets or resources a household has access to; the *social capital* refers to a household's relations, networks, affiliations and associations; and the *human capital* refers to the individual skills, knowledge and labour capabilities of a household, including health and the totality of their time (DfID 2001). The personal and external context of a household, identified to influence household energy behaviour in the frameworks discussed in Section 4.2.1, also represent and influence the livelihood capitals of a household.

If therefore, an existing chain of demand stages form part of the livelihood of a household (or its means of living), underscored by a capability at the basic capabilities stage, then its demanded option at each stage — assuming that there are options — is dependent on the livelihood resources available to him/her/them and any constraints they present. It is difficult to speculate on the different considerations that will take place from person to person and the trade-offs they are prepared to make between their different livelihood capitals, and trade-offs between different demands at different stages of multiple livelihood consumption chains; but what is relevant is that the more important a (basic or secondary) capability is to an individual or a household, the more important it is to engage with an activity or system of fulfilling it at each previous stage of the consumption chain — an autonomous consumption.

The efficiency with which households make use of their livelihood capitals can also be expected to differentiate from person to person and from decision to decision, and can be an explanation for unexpected modes of consumption; however, the emphasis placed on different capabilities will also be an important determinant of this. For example, a desire to receive information or be educated (basic capability) encourages a person to go to school, which they choose to achieve by walking over 2 hours each day; which is made possible, in part, by their human capital (ability to walk and time to do it). The energy expended walking and opportunity cost of time spent, could have been saved by trading off part of any existing financial capital and adopting a different mode of consumption for going to school, such as a bus ride; but a decision not to do the latter could have been brought about by a need to engage with the demands needed to fulfil an alternative basic capability, for which the financial capital required allocation.

If however, the person's basic capabilities were such that his/her walking energy and time, at the point of decision-making, were deemed critical to an alternative activity such that they could not be allocated to the 2 hour walk, then a different mode of consumption would have been undertaken. Applying this idea to the consumption of energy services can provide understanding for the behaviour exhibited by households, and what sustainable household energy transitions may require.

Energy services can involve various modes of consumption (or means of consump-



tion), such as periodic energy carrier purchases, technology purchase, technical arrangement/preparation, service operation, service disengagement, technology maintenance, and many more; not all of which are directly involved with the transfer of energy from resource to end-use for the undertaking of an activity. Each mode of consumption that makes up the social-energy interaction will be linked to different basic capabilities and potentially other modes of consumption in a chain. The demand options adopted at each stage in each chain, to enhance or ensure a means of living will be dependent on the livelihood capitals of a household and the emphasis given to its various basic capabilities that are associated with the social-energy interaction.

So conventional approaches to energy access will say, for a simple example; bring down and stagger the payment of a solar lantern and a household will be able to afford cleaner energy for lighting. The household may then say — as one of many decisions surrounding its interaction with the solar lantern — we have a desire for the kids to gain a good education and this requires them to study at night using this newly acquired solar lantern; but we also need to prepare food in the kitchen at this same time and so we need to continue making use of the kerosene lantern — and energy stacking takes place. In another simple example, clean cook-stove providers may say; educate a household on the dangers of indoor air pollution from traditional biomass cookstove cooking and they will be willing to purchase and make use of a more efficient stove. The household may say; there is a particular way we want some specific foods to taste, and the clean cookstove (e.g. LPG cookstove) does not facilitate this so we will use our traditional stove for this particular meal preparation — and energy stacking is the result (see Chapter 3).

Importantly, the more a demand is autonomous — that is, consumption is increasingly necessary to livelihood sustenance — the more urgent the desire to fulfil it (Galbraith 1958). The more urgent the basic capability — the demand households are most concerned with — the more urgent the modes of consumption by which it can be achieved. As mentioned earlier, of the two capabilities, secondary capabilities are subject to change between individuals, households or communities, and over time with changing individual and external contexts. Shove (2003) illustrates this with a change in UK custom on showering patterns — from weekly bathing to daily showering. The secondary capability, which is the activity of showering, has received a change in its mode of consumption due to changes in the decision environment; whereas the basic capabilities remain the same — one of self and societal respect through cleanliness, one of pleasure, one of health, and others.

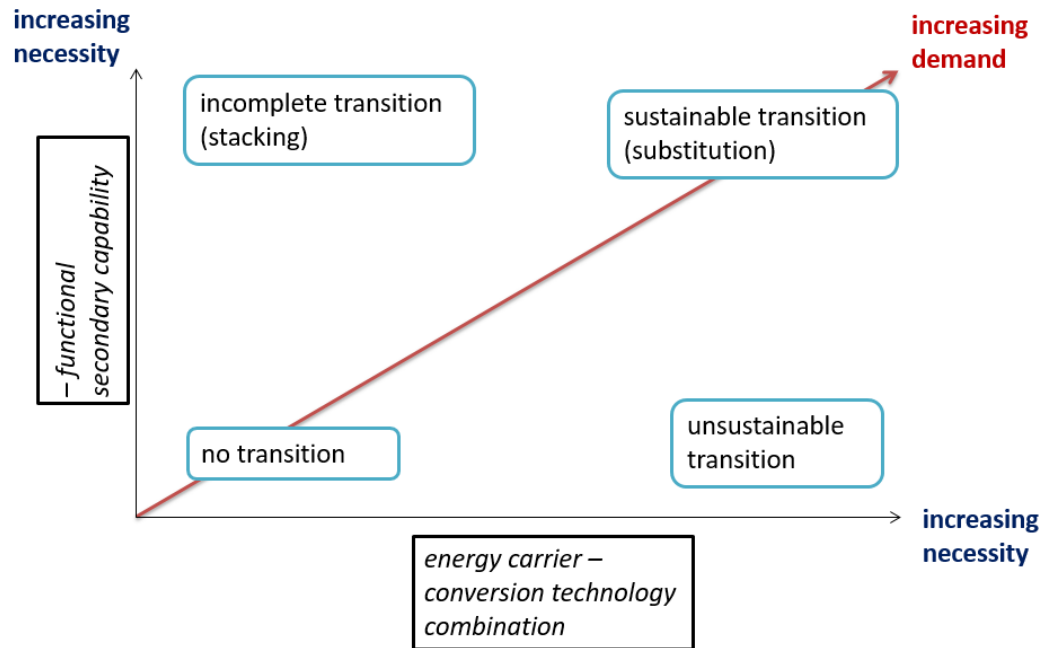
It can therefore be argued, that if the fulfilment of a secondary capability can be such that systems of modern energy consumption, and importantly the discontinuation of traditional energy consumption systems, are necessary and urgent, then sustainable complete transitions will take place. This is to say, that if a (new or otherwise) secondary capability

can become urgent (as seen with daily use of a computer in some contexts), its modes of consumption (working computer, electrical supply to charge battery) become urgent and seek to be consumed. Or if a secondary capability becomes urgent (working 9 to 5 in an office) certain modes of consumption (manually sourcing fuelwood on the farm) need to be discontinued. In the presence therefore, of competing modes of consumption for energy services (between traditional and modern), the livelihood of an individual or a household and the means by which it is sustained or enhanced, can bring forth specific behaviours.

Figure 4.9 presents an illustration of how this might result in different transitions. For a given energy service: if the desire to own or make use of a particular energy carrier and conversion technology combination is low, along with a low desire to undertake the final activity (functional secondary capability) that the energy service meets, it may not inspire transition; if the desire to undertake a final activity that an energy service meets is low, yet the desire to own or operate the elements of the energy service is high for purposes of an alternative capability (for example, a non-functional secondary capability such as aesthetic indication of social status) then the transition is susceptible to being unsustainable; if the desire to undertake the activity met by the energy service is high, but the desire for the energy carrier-conversion technology is low (perhaps due to the presence of competition, or partial compatibility) then there is a likelihood of energy stacking; if the desire to undertake the activity met by the energy service is high, and the desire to operate the energy carrier-conversion technology is also high (perhaps due to a lack of competing energy services, or full compatibility) then there is a likelihood of the old energy service being fully substituted with the new for a full and potentially sustainable energy transition.

The examples explored throughout this section only consider a snapshot of what are numerous and dynamic activities that individuals and members within a household might desire or undertake as part of their daily lifestyle, which will have an effect on the social-energy interaction for various energy services. There is a need to explore the range of considerations possible under numerous and changing personal and social contexts, constrained and supported by various livelihood resources, influenced by certain values and beliefs, and shaped by existing habits on consumption in daily life. This research takes a step to explore this; and the method by which this is done, and the findings elicited can be found in Chapters 5 and 7 respectively.

**Figure 4.9:** Conceptual framework illustrating the sustainability of household energy transitions



Source: Author's depiction

## 4.5 Conclusion

This chapter set out to answer the first research question by exploring what explanation can be given for the energy behaviour of the energy poor, to conceptualise the determinants of transitions that have been observed, from the consumer's perspective. Frameworks in the literature, drawing on models of decision-making and residential energy use from disciplines such as social and environmental psychology, have expanded on limitations of the widely adopted energy ladder and energy stacking theories of household energy transitions in developing countries. They present a basis from which past transitions can be examined to see how developments in the personal and external environment of a household are important determinants of household energy behaviour change. It is thought that energy stacking is the result of household attempts to secure their livelihoods, where use of traditional and modern fuel-technology combinations is maintained to meet the needs of the household. The relevance of these livelihood security concerns, and how they influence energy decision, go beyond the useful act of consuming energy to encompass broader areas of the human interaction with the three dimensions of energy use. With the understanding that the demand for energy is constructed and sustained by ubiquitous fundamental human desires, a conceptual framework was put forward to explain the sustainability of household energy transitions. Among the set of explanations given to different types of transitions observed in energy access efforts, it postulates; that if the activity made possible by an energy service is

urgent to a household's livelihood, along with the *modern* fuel–technology combination by which the energy service is consumed, then sustainable substitution of an existing traditional energy service is the likely transition.

## Chapter 5

# Researching Household Energy Transitions in Developing Countries

*How can this research investigate the evidence surrounding why households interact with energy the way they do and what the evidence can inform about future household energy transitions?*

## 5.1 Introduction

In Chapter 4, the idea that individuals/households make decisions about their energy services as a part of an underlying bid to sustain and enhance their livelihoods, was put forward. This emerged from concepts in the literature that stressed the importance of personal and social environments that shape and are shaped by household behaviour. This research has then set out with the objective of exploring the postulated interactions as it answers the two remaining research questions:

2. What do the lived realities of households in rural Lagos reveal about the energy decision-making of the energy poor, and the drivers of sustained behaviour change?
3. How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways of relevant drivers, and what can this inform about facilitating the transition to modern energy services?

This chapter describes the pragmatic methodology adopted to answer these questions, introducing the selected case, Lagos Nigeria, and the reasons for its selection. Regarding research question 2, a discussion is presented on the process by which field visits shaped and informed the research objectives, and how the resulting fieldwork insights were elicited and verified; giving due attention to methodological, practical, and analytical considerations, as they pertain to cross-cultural social research. The chapter also introduces the scenario analysis adopted to answer research question 3, and discusses some of the innovative concepts used to mitigate issues commonly found in models of household energy demand in developing countries.

Overall, the process of primary and secondary data collection was carried out in two stages between May 2013 and November 2014. The first stage was spent living and conducting field research in Lagos, Nigeria; facilitating the development of a keen understanding of the issues related to energy services in the state and amongst the rural BOP. Following this was an initial examination of the primary data obtained during the first stage, using initial insights to revise and refine the conceptual framework and approach to answering the research questions. The second stage saw an immersion back into the field in Lagos, to re-engage and clarify emerging insights through elicitation of a second round of primary data collection. Finally, the data obtained in the second round of primary data collection is examined; insights which have input to the scenarios modelled in the Lagos-LEAP model, which was developed iteratively throughout time spent in and outside the field.

The remainder of this chapter is structured as follows: Section 5.2 introduces and justifies the research design and the case selected, in accordance with the research aims presented in Chapters 3 and 4, and the gaps in the field being addressed. Section 5.3 discusses most of the work undertaken in the field, through which research question 2 is

answered; critically appraising the method adopted, which encompasses discussion on the process of conducting fieldwork with households in rural Lagos communities, and how the insights were analysed and represented in this thesis. Section 5.4 critiques the literature on household energy demand modelling for developing countries, before introducing the Lagos–LEAP model used to answer research question 3, and Section 5.5 concludes the chapter.

## 5.2 Research design

The main aim of this thesis, as set out in Chapter 1, is to *investigate how the global energy poor can sustainably transition from traditional energy services to modern energy services*. In Chapter 3 some methodological gaps in energy access examinations were highlighted, which include:

- A dearth of qualitative research on *established* energy service use, whether modern or traditional, as a means to learn about the social-energy interaction and the drivers of sustainability.
- A dearth of studies in this field that consider the entire scope of household energy services during examinations of affordability, availability, behaviour, transitions, sustainability, and other goals on the agenda for learning.

When seeking to understand the energy transitions of the energy poor, there is a need not just to consider the range of energy services a household engages with — and how they individually and holistically influence behaviour — but also consider other individual and shared societal engagements of a household (see Chapter 4). Undertaking research grounded in the view of demand as a social construct, encourages the use of qualitative research methods; including the use of interviews or other ethnographic techniques to obtain observed and self-reported determinants of energy behaviour (Wilson & Dowlatabadi 2007). The nature of research question 2 makes it suitable for such techniques.

On the other hand, the forward-looking nature of research question 3 requires greater reliance on quantitative techniques to provide measurable outputs of change. Thus, a pragmatic approach to the overall research methodology is adopted; one that is not governed by a particular paradigm, but purpose-selected based on the questions being asked (Morgan 2007, Small 2009, Teddlie & Tashakkori 2010). The third research question also aims to utilise insights from research question 2, as it seeks to explore possible transitions. This lends the work to a method-mixing approach that is similar to that of an “exploratory sequential” mixed-method design; where work begins with the qualitative phase of the method, in a two-phased interaction, before the results of the first phase inform the second quantitative phase (see Greene et al. 1989, Creswell & Plano Clark 2011).

Rather than conforming to the above or any particular template for mixing qualitative and quantitative methods, this research's method places greater emphasis on pragmatism, as mentioned earlier. Therefore, it heeds Morgan's (2007) proposal of a framework that encourages movement between dichotomies of: (i) the manner in which conceptual discussions had in Chapter 4 are connected to data and insights obtained from the field (*induction and deduction*); (ii) the relationship between the researcher and the overall research process (*subjectivity and objectivity*); and (iii) the inferences that can be made from insights obtained (*context and generalizability*). These serve as guiding principles to the research philosophy and take shape in the strategies adopted in both the qualitative and quantitative strands of the work and how they are integrated. These considerations are further discussed in the subsequent sections of this chapter.

### 5.2.1 The case

The case selected for research needed to allow the exploration of the concepts discussed in Chapter 4 and contribute to plugging the methodological gaps highlighted in Chapter 3, while answering research questions that require diverse methods, under limited human, time, and financial resources. Given the importance of context when dealing with issues of energy poverty and access (see Chapter 3), it is useful to design a case that compares insights from vastly different contexts, such as the energy poverty and access situation in two or more cases from different countries or continents. However, limitations on time, financial and human resources, and the research interests made it suitable to restrict the case to one region (particular state within a country). Nevertheless, the case is structured such that varying contexts within the chosen region are explored to facilitate rich and diverse insights from the field in accordance with the research needs.

Another important characteristic for the case is the relevance of energy poverty. Importantly, this work seeks to gather insights from households and communities experiencing energy poverty to various extents (or varying tiers of energy access — see Tables 2.1 to 2.5), and this is facilitated in the contexts chosen for fieldwork within the case region. The Federal Republic of Nigeria is in the top 3 countries globally for per capita energy poverty with both electricity and clean cookstoves (World Bank 2017a), making it a suitable country within which the case can be selected.

Lagos state, in Southwest Nigeria, was selected as the region for study; with a number of its rural communities selected as locations for fieldwork. There are other regions in Nigeria, such as the far West and the Northeast, that exhibit strong characteristics of energy poverty and remoteness, but it was not suitable to situate fieldwork in those regions for a number of reasons. Firstly, groups of communities in those areas tend to have limited variance in their nature of energy poverty and would limit the diversity of insights and the



opportunity for comparison. Whereas, the communities chosen in rural Lagos exhibit enough differences in energy access, development, and social and cultural demographics to achieve the desired heterogeneity of context; which can aid transferability of the study insights for the understanding of other contexts (Schofield 2002). In addition, many of the remote rural locations tend to have experienced NGO/donor-involved activity with dedicated energy access project/programmes, making them unsuitable for the methodological requirements of this research. The uncertain security situation in the north-east of the country made the area unsuitable for fieldwork, as the FCO (Foreign and Commonwealth Office) advise against all (but essential) travel to these regions. It would have increased the diversity of insights to have included communities from western Nigeria in addition to the Lagos communities visited, however constraints on time, financial resources, and community access all made it necessary to limit the scope of the areas being researched.

The support of state institutions for gaining access to communities, secondary data, and for practical support in the field was crucial for the work undertaken, and Lagos state made this available in the form of the Lagos State Electricity Board (LSEB) and the Lagos Centre for Rural Development (CERUD). The former is an arm of the state energy ministry and provided access to state-level data, and energy sector institutions; while the latter undertakes state-sponsored works in rural areas of the state, and served as a key facilitator for the fieldwork process. The secondary data made available by the LSEB is another reason Lagos was selected for this work rather than other Nigerian states that have higher instances of energy poverty. Answering research question 3 will require the use of secondary data on energy use, social demographics; all of which are not well developed in most other states in Nigeria. Importantly, this also meant analysis for question 3 at the state level; a geographical scale higher than that of the scale used for fieldwork in answering research question 2, which focuses on rural Lagos alone. Analysis at the state level fits in with the objectives of the third research question, and is further explained in Section 5.4.

The research did consider including communities in urban and slum areas of Lagos in the fieldwork, so as to gather greater representation of Lagos state as a whole, for the purpose of transferring insights between research questions 2 and 3, but this would take primary data collection beyond that which is required to answer the second research question. Importantly, the critical institutional support provided by CERUD was only limited to rural Lagos, and did not cover urban and slum regions of the state. Furthermore, this work aimed to enrich the data collection process by selecting a group of communities for fieldwork, that would all be familiar to the participants involved, regardless of their residence.<sup>1</sup> This allowed participants the opportunity to present their experiences in a wider context, which could then

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<sup>1</sup>Rural residents in Lagos were knowledgeable about other rural areas outside their resident community. They were also knowledgeable about areas in the urban and slum regions of Lagos, but with much less coverage.

be cross-examined by further field observation and during subsequent interviews to glean new insights and/or verify information. Any attempt to also adopt such a rich examination of the field in slum and urban areas of the state would have necessitated more time and financial resources than were available. The change of geographical coverage between the qualitative and quantitative phases of the study suggests unsuitability for using insights obtained in the former to shape the selection of drivers used to develop scenarios in the latter. Acknowledging this, insights from the field mainly served to refine and support driver-selection that was largely based on relevant external environment drivers identified in the literature, as presented in Chapter 4, and those observed to be relevant to Nigeria and Lagos, as presented in Chapter 6.

## **5.3 Fieldwork**

### **5.3.1 Fieldwork strategy**

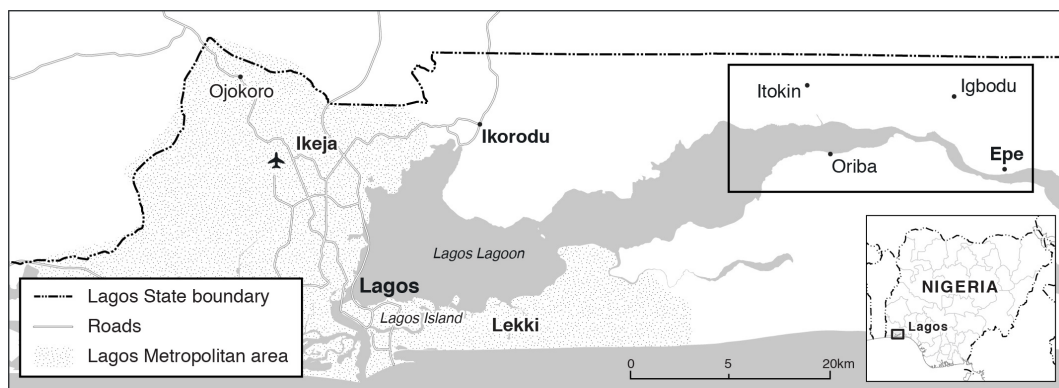
Chapter 4 presented frameworks from Van Der Kroon et al. (2013) and Kowsari & Zerriffi (2011) that highlighted some of the factors affecting household energy decision-making. These factors ranged from individual attitudes, experiences and capabilities, to the external socio-cultural, natural, political, institutional and market environment in which they are situated. This indicates the need for an appreciation of the context at scales from the micro to the macro, and a potential for analysis across these levels. The second research question's main focus is on behaviour and transitions at the household level, so it is the main area of primary data collection and analysis by which the question is answered. However, it was necessary to build a clear picture of the context particularly around the external conditions influencing household behaviour, in order to appreciate the transition dynamics at the local level (Elias & Victor 2005). This was done through various interactions with other stakeholders, including interviews and meetings with technology/fuel providers, wholesale energy providers, state energy ministries and other (details provided in Section 5.3.2); in addition to a detailed review of the literature at the local, state, and national levels. This context is presented in Chapter 6 and informed work in the field, analysis, and writing.

The specific contexts of each local community included for household interviews are presented in detail in Chapter 6. The reasons behind their inclusion are briefly introduced here. Three communities from the Epe local government area (LGA) in rural Lagos were selected for the first stage of the fieldwork; Igboodu, Elujo-Imowo, and Oriba. As the fieldwork developed between the first and second stage, the number of communities used in the fieldwork process increased to five with the inclusion of Ketu and Itokin; primarily because of the relevance of their contexts for enriching insights. Other reasons involved the practicality of executing the research process, which — as is often the case when conducting research of this nature — ran into stumbling blocks (Holliday 2007, Leslie & Storey 2003b);

necessitating improvisation and in some cases re-evaluation of the fieldwork plan.<sup>2</sup> These fieldwork implementation aspects are discussed at length in the sections that follow.

The communities were selected due to differences in characteristics such as; availability of energy services/infrastructure, community remoteness, and other socio-economic characteristics. Given that all communities started out as villages with a cluster of indigenous families that owned land upon which they built their homes and undertook commercial/subsistence farming, the resulting differences serve to provide a view on the type of changes that take place in rural Lagos as some communities develop, and the types of social, cultural and economic changes that can ensue, and their impact on energy transitions. The Ketu and Itokin communities — fortuitously situated — have become small towns with community market centres that connect three major localities by road (see Figure 6.5). The remaining three communities are much more primitive, only one of which is connected to the grid (Igbodu), and another much more remotely located (Oriba).

**Figure 5.1:** Map of Lagos



*Source:* Author's depiction

*Note:* The map indicates the region in which fieldwork was undertaken in rural Lagos. Only Itokin, Igbodu, and Oriba of the five communities included in the work are depicted, as well as Epe's main town (indicated 'Epe' in the map). A more detailed map of the fieldwork region, indicating the location of all researched communities, is illustrated by Figure 6.5 in Chapter 6.

In eliciting insights about household energy behaviour there are a number of research approaches that can be used. At one end of the spectrum, ethnographic methods — which involve participant observation and interviews via full immersion within the group of interest for an extensive period of time — can be used to elicit detailed qualitative insights about the group's or subject's social interactions within their environment (Schutt 2009, Kearns 2010). Towards the other end of the spectrum, survey methods can be relied on to obtain specific answers to specific questions, and the data analysed quantitatively on the statistics that describe it (Schutt 2009). Although the latter sacrifices richness of information per subject, it is a more practical means of obtaining a representative sample of a case (Nie & Erbring

<sup>2</sup>See short brief on the researcher's experience in the Oriba community in final paragraph of Section 5.3.2.

2000). What is important is to select an approach suited to the objectives of the study, while acknowledging and treating the limitations of the chosen method (Carter & Little 2007). Research question 2 is asking *why* households interact with energy the way they do. This involves eliciting information around a participant's reality, around motivations, around histories, opportunities and future hopes. The process expects to encounter both new doors of inquiry not previously known to the researcher nor found in existing literature, and also reveal nuanced relationships observed for other contexts in the literature. Therefore, the close-ended nature of a questionnaire survey, which limits the breadth of consumer responses, is not suitable as the primary method for this research.

Qualitative research on the other hand permits the above desires of the study, as it focuses on asking "open questions about phenomena as they occur in context rather than setting out to test predetermined hypotheses" (Carter & Little 2007, p. 1316). The aim here is to generate rich empirical data through in-depth investigations and analysing the text data in a bid to understand the meaning of human behaviour (Flyvbjerg 2001). An interpretivist epistemology is a key aspect of this work's qualitative strand, which endorses a belief system that relies on multiple interpretations of the knowledge being uncovered (Bryman 2016). An important implication of this is the subjective nature of the process. Qualitative researchers are therefore encouraged to acknowledge the part played by their positionality in the research process, and its influence on the knowledge uncovered through a process of reflexivity (Sayer 1992, Creamer 2006). The roles of reflexivity and positionality in qualitative research in general, and in this research are discussed later in this chapter (see 'practical reflections' subheading under Section 5.3.2).

A feature of qualitative research, which forms a major part of the fieldwork undertaken, is its unpredictable nature; to the extent that decisions made about data to be collected need to emerge from discoveries about the research setting (Holliday 2007). Thus, it is difficult for qualitative researchers to know *exactly* what nature of data they will collect before beginning the fieldwork process. Indeed, qualitative research is generally underpinned by an iterative process involving data collection, analysis, conceptual/theoretical induction, and refining/reformulating points of inquiry (Bryman 2016, Grbich 2013).

In accordance with an iterative approach to qualitative research, the fieldwork was conducted in three separate portions that involved a scoping period and two main phases between May 2013 and November 2014 (Appendix A elaborates on field experience that illustrates the importance of the scoping study). An initial one-month scoping period in May 2013 was used to examine the nature in which questions coming out of the literature were related to the case and can be answered by it. This was followed by the first stage of fieldwork which coincided with the collection of data required for answering research question 3, over a four-month period between September and December 2013. This stage

placed an emphasis on obtaining a multitude of perspectives on how users interact with energy services and identify concepts as they begin to emerge; informing discussions had in Chapter 4. The final stage made it possible to refine activities in the field in order to further explore concepts, leaving open the opportunities for new insights. This iterative process was also used — to a lesser extent — throughout time spent in the field, with constant examination of the data elicited (preliminary data analysis) in order to guide the direction of inquiry (Grbich 2013).

Eliciting unbiased truths through direct communication or observation are not without their issues. Interviewees can purposely or mistakenly misrepresent the truth; researchers can misinterpret the meanings behind observations; subjects may alter behaviour due to knowledge they are being watched or due to an awareness of the ongoing investigation (see Section 3.6.1), etc. (Schensul et al. 1999). This research therefore uses multiple methods to obtaining evidence from the field, which include the use of: semi-structured interviews, observation, a review of the literature, and focus group discussions (see Table 5.1). It also takes a number of practical steps to fieldwork to ensure the elicitation of quality data, which are discussed in relevant sections of this chapter.

Ethnographic research — which places great emphasis on observation, and would require living within the communities over a long period of time and engaging directly with the energy services used by participants — is not required for answering research question 2. This is because the research has a focus on consumer experiences and perceptions, not the researcher's; and there is an appreciation not just of the present but also of history and the future. While ethnographic research can incorporate these aims, it would collect more data than is required to achieve them and answer the research question; which would be an inefficient use of limited time.

However, it is difficult to obtain evidence on the motivations or thought-processes behind the actions of a person without at least speaking with them directly. Therefore, although multiple data collection methods were adopted during community visits — each visit lasting over half a day — the fieldwork strategy was founded primarily on semi-structured interviewing; or “intensive” interviewing (Schutt 2009). With the use of semi-structured interviews, questions can be framed according to general areas of inquiry desired by the work, but allows enough flexibility for conversations to take shape in a natural way. The aim was to obtain a comprehensive picture of a participant's perspective by listening to their “interpretations of their experiences and their understanding of the world in which they live and work” (Rubin & Rubin 2005, p. 36). Appendix B presents the question framework used for the household semi-structured interviews in both stages of fieldwork, showing the rationale behind each question and the general structure adopted.

**Table 5.1:** Summary of data collection methods used to answer research questions 2 and 3

Method of data collection	Data type	Description	Groups method employed with	Number undertaken	Further info
<i>Research question 2</i>					
Audio recorded semi-structured interviews	Primary, qualitative	In-depth one-to-one interviews. Flexible structure for conversations with broad areas of inquiry to direct conversations.	Household decision-makers; senior staff of modern (clean) energy technology retailers in Lagos	91 (83 households interviews; 8 energy technology retailer interviews)	Section 5.3.2 and Table 5.2
Focus groups	Primary, qualitative	Unstructured group discussion on community energy services and behaviour with locals in a community.	Group of locals in Igbodu, Elujo-Imowo, and Oriba.	3	Section 5.3.2
Unrecorded semi-structured interviews	Primary, qualitative	Semi-structured interviews with broad areas of inquiry about Lagos and Nigeria's energy market and external decision environment.	Traditional and modern (fossil-fuel based) technology retailers; end-user financing institutions; multilateral development institutions (MDI); public institutions; state ministries and parastatals	15	Section 5.3.2
Soft participant observation	Primary, qualitative	Visiting and undertaking interviews in natural environment of participants (e.g. homes, stalls, shops), enabling observation of their surroundings and natural processes.	Households	67 households	Section 5.3.2
Secondary data examination	Secondary, qualitative and quantitative	Epe, Lagos and Nigeria context building.	N/A	N/A	Chapter 6
<i>Research question 3</i>					
Unrecorded semi-structured interviews	Primary, qualitative	Semi-structured interviews with broad areas of inquiry about Lagos energy system, trends, and future.	Energy companies; government institutions; academic institutions; locally-based multilateral organisations; other research institutions	13	Table 5.3
Secondary data examination	Secondary, qualitative and quantitative	State energy consumption database development, and scenarios development.	N/A	N/A	Chapter 8

### ***Fieldwork in developing countries***

There are a number of considerations western researchers must be mindful of when undertaking social research in developing countries to ensure a successful process, given the differences in issues such as culture, languages, and socio-political gradients (Sidaway 1992, Murray & Overton 2003). Matters concerning the researcher's purpose in the field, their conduct in the field, and the representation of the field in writing are all important considerations in order to safeguard both the researcher and the researched (Cupples & Kindon 2003, Leslie & Storey 2003a). Much attention has been given to the role of power relations between a western researcher and local people in developing countries, and has assisted the former in being conscious of naturally occurring ethical issues (Kobayashi 1994, Rose 1997, Sultana 2007). Discussion under this subheading introduce some of the strategies adopted to manage these cross-cultural issues, before discussion under the 'practical reflections' subheading in Section 5.3.2 reflect on how these issues were managed in practice.

Research ethics can be compromised if a conflict of interest is not acknowledged and addressed, or in the case of the global poor, if research becomes exploitative. These ethical issues are most likely, when work is being conducted in partnership or on behalf of organisations that are stakeholders in local proceedings (Wolcott 2005). Being a government parastatal, CERUD's presence during the household interview process can present such a threat, and thus had to be managed. Their role in the field was limited to that of assistance and did not impose any objectives of their own over the course of the research process. They sought only to learn from the fieldwork insights. It was therefore necessary to ensure participants were aware of this, and the purpose of our presence in the field; making it clear that their participation was not mandatory, but voluntary. Clear introductions were made at the start of each interaction, in addition to verbal consent to undertake and record the interview, as well as a guarantee of anonymity during representation in writing (Schutt 2009).

It is also important to ensure a researcher's work is not exploitative of those being researched; and one important issue in cross-cultural research is ensuring the voices of local people are heard, and not conducted to legitimise the voice of a researcher's preconceived notions (Scheyvens, Nowak & Scheyvens 2003). The language barrier common in cross-cultural research — and the potential need for research assistants, and its potential impact on how voices in the field are represented — was relevant to this research. The practical handling of this issue is discussed later in this chapter ('practical reflections'). The aim also is for the results of this research to be shared with local partners (LSEB and CERUD), and in peer-reviewed academic journals; with both local partners aiming to build on insights to support strategic recommendations to the government. Following the conclusion of this research, there is also an intention to visit field locations to educate locals on actions that

can be taken to alleviate them of energy poverty.

In addition to household interviews, stage 1 of the fieldwork also involved information gathering through meetings and interviews with a range of energy stakeholders, whilst in the communities and other parts of metropolitan Lagos. The researcher's positionality shifts during interactions with participants from such contrasting groups, given the variance in perspectives, the purpose of interactions, and the settings in which interactions took place (Mullings 1999, Sultana 2007). Discussions later in Section 5.3.2 will reflect on these issues of positionality and power asymmetry, as regards issues such as the researcher's background and relation to case setting.<sup>3</sup>

Prior to entering the field, it was important to ensure fieldwork actions would not impede local acceptance of the researcher's presence, and the work being undertaken (McLennan et al. 2014). This required careful knowledge gathering on traditional norms, politics, and lifestyles of the communities being visited. For example, part of the preparatory work considered cultural views of women and their roles in the communities. Because this research intended to include them as participants, it was necessary to make sure that such interactions did not disregard cultural norms relating to women; as can be significant under certain contexts (Scheyvens, Scheyvens & Murray 2003).

Also important to local acceptance of a researcher is the approach used when entering the field. A *gatekeeper*, who Schutt (2009, p. 328) describes as "a person in a field setting who can grant researchers access to the setting", is an important tool; particularly in primitive areas of developing countries where much of western culture remains foreign, or areas that have experienced negative outsider interactions. The primary gatekeepers in this research were CERUD. However, as discussions in Section 5.3.2 will show, both CERUD and the researcher had to navigate gatekeepers in each community; gatekeepers in the form of village heads and group leaders, who all had the mandate to grant or deny access to work in the field (Leslie & Storey 2003b). Appropriate awareness and management of this truth meant that these actors proved to be invaluable proponents in the success of the fieldwork.

### 5.3.2 Data collection and Fieldwork in Lagos

The previous section elaborated on the strategic approach utilised in this fieldwork and some of the considerations had during planning. This section will discuss how participants were selected to partake in interviews, and the practical execution of work in the communities and in observing the case context; including some of the challenges faced and opportunities presented whilst in the field. Subsequent sections will also touch on some considerations had when representing the field in writing.

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<sup>3</sup>Any use of the phrase, 'the researcher', concerning the practical implementation of this thesis' fieldwork, refers to the sole author of this thesis; who undertook all interviews, focus groups and meetings. All forms of external field support — such as with translation during interviews, community access and introduction, and transcription of interviews — have been clearly stated in this chapter.



## ***Community interactions***

### **1. Preliminary community meetings and focus groups**

As is often the case when undertaking fieldwork in developing country communities, introductions must be made with leaders of the community (Banks & Scheyvens 2014). In a traditional setting such as rural areas of Lagos state, these involved meeting kings (Kabiesi), chiefs (Bale), appointed community heads, and other respected interested members of the community. These were utilised as focus group opportunities to introduce the work, garner interest in its objectives, and obtain interview participants. Initial perspectives on community attitudes towards certain aspects of their energy services were also explored during these meetings. Of the three communities involved in the first fieldwork stage, the community meeting for one happened during the scoping period, while for the other two it took place early in the fieldwork. Knowledgeable informants for respective communities were also consulted during this period, for a deepening of contextual data and to finalise the strategy used during the household interview process. It is important to ensure informants are credible, although this can be difficult when the informant is a member of the community in question.<sup>4</sup> In total, meetings were had with six knowledgeable informants which included; chiefs, a school headmaster, community youth leaders and administrators.

### **2. Household semi-structured interviews**

The field of energy access is interdisciplinary and therefore requires that qualitative research be cognisant of the methodological demands from various disciplines; particularly on the issue of designing cases that are representative of the study population in order to generalize findings (Flyvbjerg 2006). However qualitative research can be unpredictable, particularly across cultures, making it difficult to obtain representative samples of a study setting, without risking “a form of imitation grounded in language” of standard survey methods, “with only a superficial” application of its meaning (Small 2009, p. 9).

The use of semi-structured interviews meant that no two interactions with participants would proceed in an identical manner, and often revealed new dynamics that required further exploration (Valentine 2005). Thus, attempting to treat the participants interviewed as a sample to represent the population cannot serve as a basis for evidence justification, and nor should the data be treated or interpreted in such a manner. Rather the usefulness of qualitative data comes from its consideration against rich contextual information about the case (Patton 2002). Surveys on the other hand, negate the need for a rich context, by asking the same questions to each participant and in most cases limiting the range of

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<sup>4</sup>Caution had to be taken with regards to preliminary information being gathered during visits with community leaders and informants, as they were susceptible to vested interests and hence may not have taken a neutral stance with some of the information being asked of them. The involvement of CERUD in the fieldwork process, who have extensive experience with the communities, proved to be a crucial source of information verification so as to limit this potential bias in the work.

possible answers. This makes it possible to objectively control variables during analysis, and speak on the significance of statistics that describe the data (Schutt 2009). Whereas the aim of selecting participants in qualitative research is to illustrate the particulars of a situation, as opposed to being representative of the population (Patton 2002, Valentine 2005).

A pragmatic approach to participant selection was adopted, making use of techniques from both purposive and snowball sampling. Gatekeepers provided access to groups and households of interest, which were selected purposively based on identified categories of relevance within the study context (Patton 2002). These categories were established prior to fieldwork, following a review of community literature, but were also developed as the insights emerged during and between the two stages. The categories were used to select participants so as to capture a wide range of perspectives in each community visited, based on differences in cultural and socio-economic characteristics that can influence or explain household energy behaviour. These characteristics include; household size, occupation, income, expenditure, residency, gender, and others (see Appendix B).

Accounting for a sample of participants that capture the range of variants for each characteristic ensured a broad breadth of rural community participants were included in the study. In some cases, once access to a group or household is obtained, subsequent participants were selected with the recommendation of the interviewee (snowball technique). Because snowball techniques can mean that participants included in the study all come from a social network (Browne 2005), the categories of relevance adopted in this work maintained a selection of participants that were appropriate to the aim of the study. Some characteristics of the 67 study participants can be found in Table 5.2.

In most instances, participants had prior knowledge of the scheduled interview and endeavoured to make themselves available for discussions over the appointed period of time. However, there were also instances, particularly in the second stage of the fieldwork process, where participants were selected opportunistically (Patton 2002) — without prior appointments, due to their observed relevance for research inclusion. For example; the inclusion of a petit-trader in the interview process following conversations that emerged from a non-research related transaction. In total, 83 semi-structured in-depth interviews with 67 households were conducted over the two stages (31 interviews with 16 participants in first stage, and 52 interviews with 52 participants in second stage; one of the participants in second stage was part of first-stage participants — so 51 new participants in second stage). Most participants interviewed were from the Itokin community (36), due to the presence of a rich variety of participant and household types.

**Table 5.2:** Interviewed participants

Fieldwork Stage	Participant Code	Resident Community	Gender
First	H1-O	Oriba	Male
First	H2-K	Ketu	Female
First	H3-IG	Igbodu	Male
First	H4-IG	Igbodu	Male
First	H5-IG	Isemboke	Male
First	H6-IG	Igbodu	Male
First	H7-EI	Elujo-Imowo	Male
First	H8-K	Ketu	Male
First	H9-IG	Poka	Male
First	H10-O	Oriba	Male
First	H11-EI	Elujo-Imowo	Male
First	H12-IG	Igbodu	Male
First	H13-IG	Igbodu	Male
First	H14-IG	Igbodu	Female
First	H15-IG	Igbodu	Female
First	H16-K	K2	Male
Second	H17-IT	Itokin	Male
Second	H18-IT	Itokin	Female
Second	H19-IT	Itokin	Male
Second	H20-IT	Itokin	Male
Second	H21-IT	Itokin	Male
Second	H22-IT	Itokin	Male
Second	H23-K	Ketu	Female
Second	H24-EI	Elujo-Imowo	Female
Second	H25-IT	Itokin	Male
Second	H26-IT	Itokin	Female
Second	H27-IT	Itokin	Male
Second	H28-IT	Itokin	Male
Second	H29-IT	Itokin	Male
Second	H30-IT	Itokin	Male
Second	H31-IG	Igbodu	Male
Second	H32-IT	Itokin	Male
Second	H33-IG	Igbodu	Female
Second	H34-IT	Itokin	Female
Second	H35-IT	Itokin	Female
Second	H36-IT	Itokin	Male
Second	H37-IT	Itokin	Female
Second	H38-IT	Itokin	Male
Second	H39-IT	Itokin	Female
Second	H40-IT	Itokin	Male
Second	H41-K	Ketu	Male
Second	H42-EI	Elujo-Imowo	Male

table 5.2 continued ...

Fieldwork Stage	Participant Code	Resident Community	Gender
Second	H43-EI	Elujo-Imowo	Female
Second	H44-IT	Itokin	Female
Second	H45-IT	Itokin	Female
Second	H46-IT	Itokin	Male
Second	H47-IT	Itokin	Male
Second	H48-IG	Igbodu	Female
Second	H49-IG	Igbodu	Female
Second	H50-IG	Igbodu	Female
Second	H51-IT	Itokin	Female
Second	H52-IT	Itokin	Male
Second	H53-IT	Itokin	Male
Second	H54-IT	Itokin	Male
Second	H55-IT	Itokin	Male
Second	H56-K	Ketu	Male
Second	H57-IT	Itokin	Male
Second	H58-IT	Itokin	Male
Second	H59-K	Ketu	Female
Second	H60-IT	Itokin	Male
Second	H61-K	Ketu	Male
Second	H62-IT	Itokin	Male
Second	H63-IT	Itokin	Male
Second	H64-IT	Itokin	Male
Second	H65-K	Ketu	Male
Second	H66-IT	Itokin	Female
Second	H67-IT	Itokin	Female

*Note:* Other details used to classify participants — including age group, marital status, residency type, household size, migrant status, occupation, farming type, monthly expenditure, monthly income, and medicinal practice — have not been included in the table for the reason of participant anonymity.

Data analysis will not attempt to compare participant insights according to classification information of each participant, since in practice it is not possible to obtain all data for each participant as can be seen in the table, but also due to the difficulty in validating the accuracy of some of the data; such as income or expenditure data, which can be subject to misrepresentation by the participant. Instead the classification is used as a guide to the types of participants there are in the study and to provide relevant information about the participant.

This thesis presents all monetary data in US dollars (\$), and uses data from the World Bank for conversions made from the Nigerian Naira (₦). Data on prices and expense are converted according to market exchange rates corresponding to the year the data was recorded. For example, 2013 prices were converted using 2013 exchange rate data from world bank (2013 US\$ = ₦157.3), and 2014 prices converted using 2014 exchange rate data from world bank (2014 US\$ = ₦158.6), etc. (World Bank 2017*b*). For participant classification purposes, all household monthly income and expenditure data is presented in 2013 US\$. All output data for cross-context comparisons have been adjusted for purchasing power parity (PPP) with international prices for the corresponding year (unless otherwise specified; such as with poverty lines), and are referenced accordingly when such data is used.

As previously stated this was the primary activity used for answering the second research question. Therefore, careful attention was given to the interview process to ensure the

elicitation of credible and reliable data, including: the duration of interviews, the timing of interviews, the participating member of the household, location of interviews, and the recording of data and information. These issues are discussed for both fieldwork stages below.

Interactions with participants were in-depth, and most participants in the first stage were interviewed on more than one occasion due to duration requirements and in order to enhance the process by which information was being elicited.<sup>5</sup> Splitting interactions alleviated a potential problem of diminished insights; which could result from lower-quality interactions in the event of fatigue on the part of all involved in the interviews (Parfitt 2005). This also made it possible to use the temporal dimension to enrich the process of inquiry. For example; in one interview case, a period of national festivities separated interactions, and this provided opportunity to examine responses the participant had previously made in the initial interview and their resulting behaviour over the festive period. In numerous cases, such dimensions proved to be a springboard for other important insights.

It was important that participants had expert knowledge on the dealings of their household and energy service interactions within their homes; meaning that interviewees had to be decision-making members of their household. The compilation of participants therefore included husbands, wives, and single self-dependent adults. They were deemed ‘experts’ as they possessed the foremost knowledge on the area of interest (Schutt 2009) — their household energy service interactions.

Practical execution of interviews was based on situations most conducive for participants; this included the utilisation of CERUD facilities, which was based in the Igobdu community (on occasion during follow-up interviews). However, interviews were predominantly conducted in/outside the homes or work places of the participants, which proved — as suggested in literature — to be the most comfortable and convenient location for participants (Valentine 2005, Willis 2006). Interviewees relished the responsibility of hosting the interview process; providing benches and chairs for all involved. Another important reason for conducting interviews at participant premises was to facilitate observation as part of the data collection process. The added insight to the living and working conditions of community members made it possible for all participants and the researcher to use the surroundings to enrich the interview process and enhance communication. Interviews could draw on situations happening in real time to aid questions, and observations provided new avenues of inquiry.

It was beneficial to record all household interviews for a number of reasons. Firstly, it strengthened the continuity of the interview process by alleviating potential distractions

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<sup>5</sup>Many of the household decision-makers interviewed were farmers, who take on other vocational activities over the course of their day; as a result it would be impractical to conduct an interview with them spanning multiple hours at once.

from note-taking (Schutt 2009). Secondly, it made it possible to re-visit interviews in their entirety at a later date, bringing forth further insights. Participants were made aware that all interviews would be treated with anonymity, and this may have contributed to their ease with being recorded.<sup>6</sup>

For interview analysis — which will be discussed in Section 5.3.3 — it was necessary to have the recorded interviews transcribed. For stage 1, this was conducted by the researcher with the aim of using the process as an opportunity for reflexivity as recommended by Davidson (2009) (more on reflexivity under the ‘practical reflections’ subheading). This proved to be a lengthy process and it was decided that outsourcing the transcription of interviews conducted in stage 2 would be a more efficient use of time. In doing this, it was necessary to ensure the utilisation of a transcription service provider that could relate to the case setting, in order to ensure complete understanding of the formal and informal language used by speakers on the recordings. This task was undertaken by a professional transcription service provider based in Nigeria, *Transcripbox Nigeria*. Cross-examination of the outsourced transcripts against the original audio recordings was undertaken by the researcher to ensure the accuracy of the transcripts to be analysed, and to facilitate the useful process of reflexivity.

Insights coming out of stage 1 of the fieldwork suggested a need for more examination of the dynamics pertaining to a household’s surroundings (external context) and how they influence energy behaviour and transitions. These revelations from the first stage were part of the process of induction that encouraged concepts developed in Chapter 4. It also made it relevant to introduce the Itokin and Ketu communities to the fieldwork which increased the diversity of community contexts, making it possible to further compare emerging themes. In total, four communities were involved in the second stage of fieldwork. The reason for omitting one of the communities previously used in the first stage of the fieldwork is clarified at the end of this section.

It is worth noting that similar to other rural smallholder farming regions of the developing world, seasonality plays an important role in the welfare of communities involved in this research; and thus, the nature of their daily lives, and the scope of residents in the community.<sup>7</sup> This can make it relevant for the second stage of fieldwork to be conducted during a different season to the first stage, but this approach was not adopted. Instead both stages were conducted during the same period, one year apart, towards the end of the mid-season and early harvest period for a number of crops (USDA n.d.).

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<sup>6</sup>Households did not seem to be influenced by the presence of a recorder. What was noticed during the scoping study, is that it was important not to give an impression that the purpose of this work was government-led, as this prompted a participant desire to have their words shared and their names quoted, and could have had other implications for the legitimacy of the interviews.

<sup>7</sup>Section 6.4 will show that during farm periods of pre-planting and harvest, communities receive an influx of temporary migrants from urban locales seeking work as farm labourers, therefore altering demographics and thus practices within some communities.

The advantage of conducting one of the fieldwork stages perhaps around early planting season over March, April and May, is it could have elicited information showing differences in how people perceive their energy issues at different times of the year; or facilitated observational evidence of change, which could also serve to enrich interview proceedings. However, taking such an approach would have introduced another dimension — to a case that already comprises multiple dimensions — that would need to be considered, explored and accounted for during data collection and analysis. This would have increased the case complexity and made the process by which the data was analysed, understood and drawn on to make inferences, somewhat problematic.

Nevertheless, and importantly, this potential limitation was treated by capturing seasonality in the nature of questions asked. Participants were encouraged to compare their behaviour across seasons and under different circumstances; and from the clarity of their responses, suggested an appropriate recollection of their behaviour at other periods of the year. Had the fieldwork method adopted been of a more ethnographic nature — where observation plays a greater role in the generation of insights — then fieldwork across seasons would be of higher importance.

### ***Observing the national, state, and local community context***

Publicly available literature, which is useful for generating advanced knowledge of the field, was scarcely available for the communities that formed the case setting. The scoping study made it possible to directly obtain resources from academics and other institutions directly engaged with rural Lagos; particularly CERUD. In addition to information obtained in meetings, literature on the social, cultural, natural, economic and infrastructure characteristics of the communities facilitated the development of a rich historic and current picture of the communities. This is presented in Section 6.4 along with relevant references, after being built on by information coming out of activities during fieldwork. State surveys also proved useful for socio-economic data on the wider Epe rural area. Introductory meetings were also conducted with public and private institutions relevant to the energy sector in Lagos and Nigeria during the scoping period, ahead of detailed discussions during the first fieldwork stage.

The first stage of fieldwork also involved activities used to build a rich context on the external conditions in which households in these communities use energy. This involved the use of multiple methods of inquiry with multiple sources to maximise the breadth of insights, deepen understanding, and verify information (Bryman 2016). Activities included; reviewing information from secondary sources, interviews, and formal and informal meetings with stakeholders. The approach used during personal interactions was dependent on the stakeholder in question. Interactions were with stakeholders that have expert informa-

tion on their respective involvement with energy and non-energy sector (e.g. other critical infrastructure development) activities that can influence household energy behaviour.

For organisations with easily accessible information and contact details online, contact was made prior to commencement of fieldwork via email and phone calls to arrange meetings. A number of stakeholder meetings were also obtained through third-party introductions from key institutional contacts made during the scoping process or from prior meetings. All meetings were conducted at the offices of participants from each group, utilising the appropriate level of formality and presentation in each case (Willis 2006). Meetings and interviews with energy market stakeholders also adopted a semi-structured format to ensure useful information was obtained with the opportunity for insights not previously acknowledged. This also ensured that participants did not purposefully or accidentally carry the discussion down a path not relevant to the aim of the meeting (Schoenberger 1991). The various groups of stakeholders included for discussion are presented below.

1. **Five local traditional and modern (fossil fuel based) energy technology retailers (*traditional wood stove retailer; private petrol generator retailers — two; energy appliance traders — two*)**

These actors were informal in nature and were contacted during time spent in the field. Making contacts with them involved impromptu ventures to the Epe town market and introducing the purpose of the visit to shop owners, requesting their participation with little notice. Appropriate ethical procedures, particularly in receiving consent, were maintained at all times. This group of participants were consulted based on their role in the state energy technology value chain. Retailing technology to end-users in rural areas, they represent key networks that facilitate the supply of stand-alone off-grid energy services in these areas (Upadhyay et al. 2013).

2. **Eight modern (clean) energy technology retailers (*ICS wholesaler and retailer; stand-alone solar lanterns wholesaler and retailer; SHS retailers; community decentralized mini-grid service provider; LPG stove retailer*)**

It was important to generate a clear picture of the current penetration of modern (clean) forms of off-grid energy services in the state, and to identify plans and potential for its growth from the perspective of industry participants. This group includes international and regional organizations that have partnered with local institutions or have branched out their activities to Lagos and Nigeria. Local businesses that have technical partners overseas are also amongst this group and together they give a view on their experiences and potential for sector growth with respect to service to consumers and market facilitation with policy makers. Recorded semi-structured interviews were utilised with this group of



stakeholders, in order to enrich the process of knowledge gathering and obtain insights not available in the literature. Participants were selected to cover as wide a range as possible on the typology of off-grid service and technology providers. The process necessitated and ensured that interviews were with senior figures within businesses that have knowledge of and involvement in strategic decision-making.

**3. Three end-user financing institutions (*state microfinance fund administrator; two private microfinance institutions (MFI)*)**

Meetings with microfinance institutions shed light on the state of end-user financing in Lagos state. The experiences of lenders and the administrator of the state fund (Lagos State Microfinance Institution (LASMI)) informed the appetite for engaging with consumer financing along the value chain in the state. This made it possible to contrast information obtained with household perceptions of consumer financing.

**4. Two multilateral development institutions (*International Finance Corporation (IFC); United Nations Development Programme (UNDP)*)**

Development institutions play an important role; undertaking a range of functions for the provision of energy access in the developing world. Resident institutions in the country with activities encompassing energy include the UNDP and the IFC. Meeting with these organisations provided insights on donor strategies around energy access in Lagos and wider Nigeria.

**5. State institutions (*Bank of Industry (BOI); Standards Organisation of Nigeria (SON)*)**

Nigeria's Bank of Industry is a key institution in the provision of finance for development in the country. A meeting with them sought to obtain information on any activities the bank is undertaking, not just in energy, but also in the development of regions in the country — such as that of the case study setting. Just as with the MDIs and MFIs, interaction with the state development financing institution was in the form of a meeting with predetermined points of inquiry. Notes were taken on key themes emanating from conversations. The facilitation of quality product importation is an important talking point in the field of off-grid energy services (see Chapter 3) and Lagos represents a major point of entry for imported products to Nigeria (Upadhyay et al. 2013). It was therefore important to also meet with the Standards Organization of Nigeria, who has the mandate to ensure quality control of domestic and international products in Nigeria.

**6. State ministries and parastatals (*Lagos Ministry of Energy; LSEB; CERUD*)**

Interaction with this group was an ongoing practice throughout both stages of fieldwork, as they were worked with closely and proved to be key proponents in the collection of primary and secondary data used to answer both research questions 2 and 3. They were selected as primary contacts for the strategic execution of this research due to their legal mandates, which puts them at the centre of their respective sectors, in a country where national controls remain pervasive. Other public institutions were consulted for secondary sources of information during fieldwork, such as state planning, transportation, and housing ministries and parastatals, even though question and answer sessions did not take place.

### ***Practical reflections***

Section 5.3.1 introduced some practical aspects to this (cross-cultural qualitative) research that must be considered and treated in order to ensure an effective field experience. Discussion under this subheading will reflect on the experience with these issues of researcher positionality, power asymmetries, ethical behaviour in the field, and other aspects of qualitative field research. The researcher is of Nigerian descent having lived in metropolitan Lagos till the age of nine, so cultural dynamics within the state were not without some level of familiarity. However, rural areas present distinct socio-cultural characteristics from those of urban areas in the state. In addition, because the researcher has been based in the United Kingdom since 1997 — being acclimatised to western culture and western way of life — it is reasonable to be given the status of an outsider (Mullings 1999, Herod 1999). This was the local perception of the researcher throughout the time spent in the field.

Early grappling with this position began when gatekeepers insisted on researcher introductions with the additive “from the UK”. Initially this position seemingly played an important part in gaining access to the field and receiving warm receptions in respective communities. However, in Nigeria there is a perception that those with the means to travel abroad are of a particular social standing (Chukwudi 2014). This perception could influence the level of exaggeration and/or understatement with which participants emphasised their situation, in the hope of achieving a particular goal — be that respect, importance, empathy, or other. Thus, it was necessary to limit the influence of this natural position by asking gatekeepers not to emphasise residency during introductions, unless necessary. There was no obvious change in reception, but it would be difficult to spot this if there was (Schoenberger 1991). Nevertheless, during interactions the position of an outsider was obvious to all interviewees due to a way of speaking that was uncommon in the region. This would shape the relationship built with all participants, with many of them building rapport through benevolent teasing about the researcher’s strong western ways despite Nigerian roots.

Interestingly, this outsider position proved a positive influence on the richness of data collected; a similar outcome observed by Herod (1999) while undertaking research as a

foreigner in Eastern Europe. Local perception of the researcher as an individual unaware of their cultures and customs saw many respondents make it a point to provide full education on the exactness of activities performed by those in their household. This improved the range of discourse to a level greater than that which would have been achieved if they felt interactions were with a local, who only needed broad descriptions of reality.

Being able to establish a rapport with participants early-on in the interview process showed itself useful (Dunn 2010). Fieldwork brings forth encounters with a range of personalities; from those willing to talk and share their opinions with excitement and energy, to those more reserved and requiring a number of questions to open up. The introductory and participant classification process seemed to be useful in achieving this, prior to energy and lifestyle-related discussions. The variance in participant personalities was a welcome indication that a potential selection bias would be greatly limited. The flexible nature of interactions facilitated by the semi-structured framework for interviews proved instrumental in empowering participants. Being able to discuss planned topics, with a freedom for conversations to explore other issues of relevance, seemed to help participants enjoy the experience; and to some extent countering asymmetrical power relations that threaten fieldwork in developing countries (Gent 2014). Furthermore, the research heeded the recommendation of Valentine (2005) to end interviews on the terms of the participant by giving them the opportunity to present any comments or questions they may have. This ensured that interactions were concluded in a respectful manner and reduced the risk of the interview process being exploitative of participants.

As mentioned earlier, the researcher's positionality had the potential to shift, and did shift in accordance with the interviewee. Interestingly, this shift occurred not only between interviews with rural locals on benches outside their homes and meetings with institutions in the city at their air-conditioned offices, but also across different groups within the communities visited. The rural setting — as will be described in Section 6.4 — is an area with diverse groups of people; particularly in terms of heritage, culture, and religion. It was therefore necessary to manage potential risks of unintentional representations that may affect local relations. There was an attempt to redress this risk by wearing plain clothing with non-threatening colours, and to repeat colour codes often, such that it would become uniform during time spent in the field. Visible jewellery was also avoided.

At the same time, it was important that locals did not misconstrue the position of the researcher, and the purpose of the interviews. During some of the early focus group meetings, there was a clear desire for development works — particularly in the area of energy — either by government or any other implementing agency. As mentioned earlier, the scoping study showed that any perception that this research was a government operation could have negative implications for the legitimacy of interactions (see footnote 6). In some instances

it encouraged local leaders to paint the best possible picture about their community, in the hope of being chosen for possible interventions. Managing these expectations was not only important for the legitimacy, but also for local acceptance. In the two least-developed communities visited there was a clear sense of cautiousness and scepticism about the purpose of this work (Elujo-Imowo and Oriba). Initially members were hesitant to speak; before it became apparent they felt this was a repeat of previous government consultations that did little for them. Clear communication, not just about what the work intends to do but importantly about *what it is not*, was necessary in this case study.

Fieldwork, in practice, involved many locals taking time out of their daily activities to sit in the sun discussing various aspects about their lives; an activity they may not consider particularly beneficial to them — at least in the short term. To ensure interviewee comfort, refreshments were provided for participants. But there was a conscious attempt not to appear to be “gift giving” (Banks & Scheyvens 2014), which — as suggested by Bleek (1979) — can serve to reassert any socio-economic inequalities that may exist. As much as an attempt was made to avoid the perception that this research sought to buy the insights of participants, the reality of dealing with different characters in the field, tied with the ensuing culture in Nigeria, meant that when some participants were offered refreshments, they made it clear they would rather receive a reasonable equivalent in monetary terms. This request was probably influenced by the researcher’s perceived positionality in the eyes of locals as discussed earlier; to be a Nigerian privileged enough to have become a western researcher.<sup>8</sup> To have rejected this alternative could likely have been deemed rude (not having due respect for culture and practices of the setting chosen for fieldwork) and may have adversely impacted relations with the participant in question and perhaps others.

Indeed, it is the view of the researcher that on occasions where this was the case, participants were not seeking to exploit the interview as an opportunity to gain money, but were simply providing a solution on how they could be appreciated for taking time out to participate in the work. Considering that many of the participants interviewed can be categorised as low-income or by some definitions poor, then the aim of providing comfort during interviews through refreshments could also be achieved — at the interviewee’s preference — as a monetary equivalent; sums of which, were not life-changing. As Wilson (1992, pp. 194-195) recommends; on the basis of an understanding of the community being studied and the locals residing within them, researchers can make contributions — be it “a listening ear and an occasional gift of food” — so long as it is done in a manner appropriate to that society.

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<sup>8</sup>There exists in Nigeria, the culture of a ‘national pie’; part of which, involves a situation where the less affluent feel it is right that those of a more privileged background — who they assume have obtained their privilege through non-transparent and potentially dubious manners — have a responsibility to give freely to the poor.

Societal norms brought forth other challenges in the practicality of interviews, beyond engaging with the poor. In one of the communities (Oriba), it was deemed necessary by the community gatekeepers to make an occasion out of an interview process; with household decision-makers interviewed in front of other interested parties. This presented an ethical issue regarding confidentiality (Banks & Scheyvens 2014). It was therefore necessary to obtain consent from participants for the interview to take place under this setup, and unexpectedly each participant from this community was enthusiastic about doing the interview under this format. There was initial concern about the impact this could have not only on the accuracy of participant responses — who may want to paint a particular picture of their lives in front of other community members — but also on the smoothness of interactions; as observers keen to share their opinions would negatively influence interactions (Willis 2006). But as mentioned earlier, one of the features of qualitative field research is the “element of unpredictability” (Holliday 2007, p. 71), and it is important for researchers to be able to improvise during their time in the field, using situations to enrich the process of inquiry. Observing conversations between community members triggered by interview questions and the interviewee’s responses was an alternative dimension to data gathering which enriched the scope of insights.

Finally, it is important to elaborate on the decision to conclude field work in the Oriba community after only two field visits. The remoteness of the community meant that accessing it was particularly difficult. On interview-days in the field, work began a few hours after daybreak in order to conclude interviews for the day, long before sundown. However, such was the treacherous terrain by which Oriba is accessed that the team truck became lodged in the muddied track, in an ordeal that tested the endurance of all involved well into the night. The safety of all involved — including the CERUD assistants who had kindly lent their services — had to be put first, and the decision was made to focus work on the communities with calmer modes of access.

### **5.3.3 Data analysis and interpretation**

As mentioned earlier, the data collected received constant examination during fieldwork in order to guide the direction of inquiry. In addition to this, a thorough analysis of household interview transcripts was undertaken following each period spent in the field. The interview recordings comprised of audio in Yoruba and corresponding English translations bi-directionally, but the transcripts were produced entirely in English for the purpose of analysis. This raised potential issues discussed earlier around local voice representation due to the use of translators (see Appendix A). Given the risk of losses in translation either during the interviews, or during stage-2 interview transcriptions which were outsourced, there was a need to revisit official recordings around critical insights during analysis. In addition,

post-interview discussions on meanings were conducted with the translator. This section will present the method adopted during post-fieldwork analysis of interview transcripts and interpretation of the data.

NVivo10 — which is a Computer Assisted Qualitative Data Analysis Software (CAQ-DAS) — was used to rigorously analyse the multitude of data amassed. The software has a set of useful tools for the organisation and analysis of field operations and data collected including; the construction of contact summary forms, coding of transcripts, user-friendly interface for categorising data, running queries on coded data, and the construction of matrices to assist evaluation. The analytical process was fluid, moving back and forth between the following steps (adapted from Taylor-Powell & Renner (2003): (i) examining the entire spectrum of data including transcripts and notes taken in the field, and making connections to help re-live the fieldwork process and highlighting important themes; (ii) using the conceptual framework to focus the analysis, creating an initial set of coding avenues, but also noting alternative avenues of interest identified in the field and spotted during transcript analysis which also need exploration; (iii) categorising codes according to appropriate themes and patterns based on particular energy behaviour, decisions, ownership, transitions, or histories — all of which can be cross-examined with other codes or themes and with participant characteristics; (iv) queries are run in a search for patterns and connections across codes, categorised themes, and participant characteristics to examine relations; and (v) using the connections assembled in conjunction with other interview stories, to interpret the findings as they relate to reasons and observations of energy behaviour and sustainability of energy transitions.

Writing is an important part of establishing the knowledge acquired; an important discovery and analytical process (Richardson & St. Pierre 2008). Representing the field research findings in writing was a challenging process, as it involved juggling between providing a complete picture of the many insightful messages coming out of the data collected and analysed, and representing what was relevant and grounded in answering research question 2; a challenge echoed by Hyndman (2001). The resulting construct was a discussion that utilised the concepts presented in Chapter 4 as a basis for illustrating the voices of the researched.

## 5.4 Modelling scenarios of household energy transitions in Lagos

The second part of this research's methodology seeks to answer the third research question: *How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways of relevant drivers, and what can this inform about*

*facilitating the transition to modern energy services?*

The purpose behind this question is to explore what policy and strategy insights for sustainable energy transitions can be revealed from the resulting developments in household energy demand under a range of pathways to the future. Achieving this aim is understandably suited to modelled projections of future household energy demand for a number of relevant pathways, which can be analysed to elicit insights. Typical for answering a question such as this, which seeks to explore future possibilities, is an analysis of scenarios (Schwartz 1991). UNEP (2002, p. 320) define scenarios as “descriptions of journeys to possible futures” which “explore the differing outcomes that might result if basic assumptions are changed”. In this regard, they generally operate as a set of qualitative stories that are evaluated by models (Ghanadan & Koomey 2005). Since the mid-twentieth century they have been employed in diverse arenas; from political decision-making, to business planning, and global environmental assessments (Jager et al. 2008). In the energy field they have been used by policy-makers, utilities, academia, and other private and non-governmental institutions for research and sector-planning purposes (Nakicenovic & Swart 2000, Cai et al. 2007, Shell 2008, Ofgem 2009, Cinar & Kayakutlu 2010, IEA 2011*b*, BEIS 2017, National Grid UK 2017, Deloitte 2017).

The general approach to scenarios is the same for these different uses, in that they focus on stories about the future, and how they can generate insights for learning and strategic decision-making (Bhattacharyya 2011). But the exact method adopted — either for developing qualitative scenario narratives, or the modelling technique used — is dependent on the purpose of the analysis, the context in which it is being employed, and whom and for what purpose the insights are meant to serve. Scenarios used for future planning, tend to employ a narrative development process that is rich in stakeholder interaction and iterative (see Winkler 2007, Jager et al. 2008). This is so that uncertainties about the future, as they are perceived by the full range of stakeholders, can be assessed and prioritised, where the most critical uncertainties form the basis of scenario alternatives. Scenarios employed in academic research do not often employ an interactive process, but can seek stakeholder insight through direct communication or from secondary sources in the development of scenario narratives (Jager et al. 2008). This is mainly because the objectives of scenarios in academic research can range from prospective planning, to more purpose-specific experimentation of potential futures to generate knowledge; for example, a focus on a particular energy resource, group of technologies, or policy.

Modelling scenarios relies on quantitatively evaluating “the systematic changes and impacts” resulting from each pathway narrated, given an uncertain future (Ghanadan & Koomey 2005, p. 1119). In this they are distinct from *forecasts*; which aim to model the most likely future and characterize uncertainties (Bhattacharyya 2011). Nevertheless, the

modelling technique differs in scenario analyses depending, not just on the focus of the analysis, but on considerations such as; the scale at which modelling is taking place (city, national, global), the case context, availability of data, segment of the energy system, uncertainties being evaluated, and the learning desired. All these considerations, as they pertain to this research, are discussed in the sections that follow. Discussion will touch on issues with modelling the energy demand of developing country households, before introducing the model and scenarios used in answering research question 3.

#### **5.4.1 Model representations of developing country household energy demand**

Chapter 4 discussed how household energy behaviour and transitions are subject to the context in which households make their decisions; an environment that consists of economic, technological, physical, social, behavioural, and psychological determinants. This idea of household energy behaviour in developing countries which draws on empirical observations is disconnected from most approaches to model household energy demand in support of energy planning and policy decision-making in these countries (Bhattacharyya & Timilsina 2010, Kowsari & Zerriffi 2011); planning that is an essential part of national economic planning (Munasinghe & Meier 1993), and more specifically for addressing energy poverty (Practical Action 2016).

The techniques typically adopted in the modelling of energy demand in the developing country context can be broadly categorised into top-down and bottom-up models. The top-down models focus on analysis at the aggregated level, using econometric modelling techniques founded on theories for establishing the relationship between energy demand and economic variables; whereas the bottom-up models rely on detailed physical or engineering representations of the relationship between activities and the conversion of energy into its useful form (Bhattacharyya 2011, Suganthi & Samuel 2012).

Bhattacharyya & Timilsina (2010) provide a detailed treatment of approaches to modelling developing country energy demand and lament the unsuitability of most models adopted. They argue that these models typically originated in or are based on the energy sectors of industrialised countries; whose economies not only differ widely, but have also exhibited different developmental pathways to those found in some developing countries (Jung et al. 2000). Most of these models adhere to the idea of utility maximization under certain budget constraints to explain the behaviour of a rational decision-maker (Kowsari & Zerriffi 2011), which as discussed in Chapter 4, is an insufficient descriptor of user decision-making regardless of context (see Section 4.2).

Bhattacharyya & Timilsina (2010) also identify specific shortcomings that make them inappropriate for developing countries. These largely surround an inadequate treatment



of the energy system disparities that exist between rural and urban areas, and the vast presence of an informal economy, which together present *inter alia*: inconsistencies in the equity of access and the consistency of supply, non-monetised transactions, the presence of traditional energies, and major technological diversities that bring forth wide variation in energy behaviour, and dynamic transition possibilities (e.g. energy stacking) that are not properly accounted for. They acknowledge that in “principle”, bottom-up end-use models are suitably placed to capture some of these features through a more disaggregated analysis; however, the undertaking of this is typically avoided due to a substantial data burden — a situation which is unaided by the data quality and availability limitations found in developing countries for both top-down and bottom-up models.

With adequate treatment of assumptions and uncertainties, energy modelling (whether of demand, supply, sectoral, or system-wide) provides a useful exercise for quantified and transparent examinations of current and future patterns of energy use; forming a good basis upon which policy objectives can be assessed (Bazilian, Nussbaumer, Cabraal, Centurelli, Detchon, Gielen, Rogner, Howells, McMahon, Modi, Nakicenovic, O’Gallachoir, Radka, Rijal, Takada & Ziegler 2010). Nevertheless, it has been stressed that when modelling fails to “encompass the complexities of this world” — which cut across social, political, behavioural, and economic realities — robust representations are at risk (Jefferson 2016, p. 5); and misrepresentations can bring forth erroneous policy prescriptions. Yet it has been observed, for example, that of the ECOWAS countries which have some sort of energy planning document, many of the limitations presented above can be found in their modelling techniques (Lee & Leal 2014).

Shortcomings in modelling demand are sometimes allowed based on the purpose of the exercise; after all, demand is only one segment of the energy system and can receive limited detail in treatment so as to give greater focus to other aspects of the energy system — such as supply (McPherson & Karney 2014). Demand dynamics may also receive limited treatment when, for example, the focus is on modelling percentage household access as opposed to intensity of use (van Ruijven et al. 2012). A few studies, encouraged by a focus on a specific aspect of energy poverty, will attempt to address some of the typical developing country modelling flaws. For example, Cameron et al. (2016) capture existing differences in expenditure levels across rural and urban areas in their modelling of cookstove access in South Asia. They also considered, to an extent, the practice of stove stacking during household transitions. But as the scope of modelling increases, the less detailed the treatment of demand in developing country models.

Some modelling tools have developed over the years with the option of incorporating features to make up for shortcomings in the modelling methodology. For example, MARKAL — a popular cost-optimization energy system model, which treats residential energy demand

at an aggregate level, modelling the sector based on exogenous assumptions — attempts to partially accommodate for a lack of treatment given to the social and cultural drivers of consumer decision-making by specifying a higher discount rate for “conservation measures and advance technologies combined with constraints on specific technology classifications” (Kannan & Strachan 2009, p, 423); i.e treating the behavioural uncertainty by increasing the perceived risk to the consumer. Nevertheless, these incorporations are typically modelled sector-wide, and are thus, unable to account for heterogeneity across different consumer groups (Ramesohl 2000).

Developed countries in some cases make use of data intensive sectoral models — such as UK housing stock models (Dodds 2014) — which are particularly advantageous in that they give detailed treatments of energy demand; from building types, to the incorporation of behavioural dimensions of energy use over time intervals sliced up to minutes (Shimoda et al. 2010). The data required for housing stock models however, have yet to be compiled in developing countries, to allow their application.

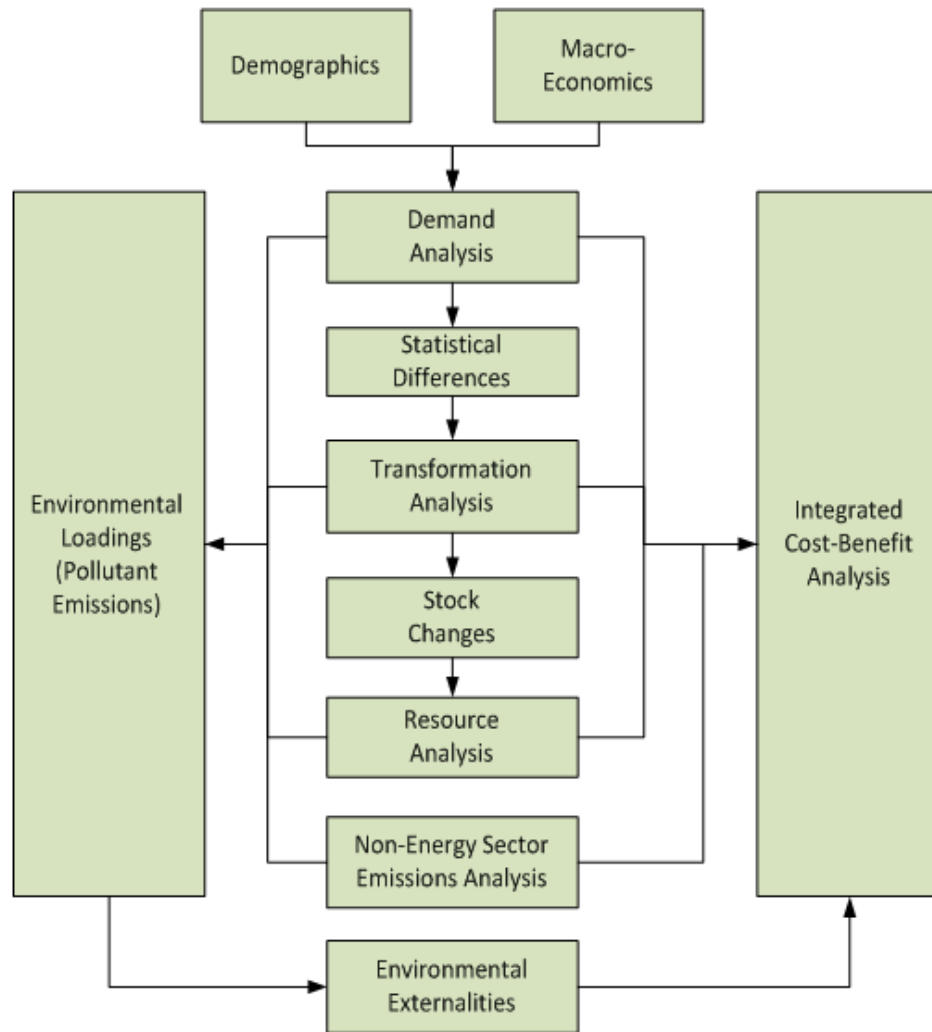
There is no doubt that policy prescriptions for addressing energy poverty issues require the support of household energy demand models that are of greater contextual relevance; which can potentially be integrated into system-wide energy models. This research will adopt a bottom-up modelling approach that will attempt to incorporate some of these salient features of developing country household energy behaviour discussed above, using the Long-range Energy Alternatives Planning (LEAP) system (Heaps 2016). This system and some of the literature on its use are discussed in the next section; before the model developed in this research is introduced in Section 5.4.3.

#### 5.4.2 LEAP modelling

The Long-range Energy Alternatives Planning (LEAP) system is a software tool developed by the Stockholm Environment Institute for energy policy analysis and climate change mitigation assessment. Since its application in 1984 for Kenya’s energy planning (O’Keefe et al. 1984), it has been used widely by government agencies, academics, NGOs, energy utilities and consultancies in more than 150 countries worldwide for energy planning and research, predominantly in the developing world (Tanatvanit et al. 2003, Mulder & Tembe 2008). It is an integrated modelling tool that can capture processes from resource extraction, through to production, and consumption across all sectors of an economy, and can also allow for sector-specific modelling (Heaps 2008).

A key aspect of LEAP, which makes it popular and suitable to the aims of this work, is its *flexible* approach to modelling; starting with the use of basic relationships that are based on physical accounting, and leading to the incorporation of simulation, using user-defined expressions. This generic nature gives it the ability to support a wide range of

**Figure 5.2:** Integrated structure of LEAP



Source: SEI (2017)

modelling methodologies; meaning that it can be designed bottom-up to capture more closely, developing country energy demand characteristics than would be possible using a top-down modelling approach (Bhattacharyya & Timilsina 2010). The advantage of using LEAP's end-use approach to projecting energy demand will make it possible, for example, to model changes in energy demand as a result of structural changes in a region's socio-economic makeup. As mentioned earlier, because of data and time concerns, most models do not take full advantage of this feature, choosing instead to limit the level of disaggregation in the model structure (Bhattacharyya & Timilsina 2010).

LEAP has been applied right across its spectrum of modelling capabilities and applications. The literature includes contributions from the public sector (EREDPC 2007), peer-reviewed journal papers (Merven et al. 2010), and PhD theses (Phdungsilp 2015). Models have typically been developed to capture the energy sectors of nation states (Islas et al.

2007, Huang et al. 2011, Zhao et al. 2011, Wongsapai et al. 2016); but have also been developed for continents (Ouedraogo 2017), cities (Nojedehi et al. 2016, Kale & Pohekar 2014, Yang et al. 2017), and in some rare cases villages (Mustonen 2010). LEAP has been used for models focussed on a particular energy-consuming sector (e.g. residential or transport) (see Hong et al. 2016, for an example of a transportation sector model), and also to model across a number of sectors (Mulugetta et al. 2007, Park et al. 2013). It has also been applied to entire energy systems (Emodi et al. 2017) as well as a particular segment of the energy system (e.g. energy demand) (Limmeechokchai & Chawana 2007) or resource (e.g. biomass supply or electricity supply) (Kumar et al. 2003). All of these examples showcase the wide-ranging application of LEAP made possible by its flexibility; typically modelled over the medium to long term, with timelines no lower than 20 years, and up to 80+ years.

Energy system models developed in LEAP typically address exploratory questions about future energy demand, supply, and associated carbon emissions under various policy pathways (Wang et al. 2011). Models focussed on supply may also seek to incorporate cost examinations (Perwez et al. 2015). Models examining energy demand alone — in addition to typical forward-looking questions about the progression of demand under different policy pathways (EREDPC 2007) — can sometimes take a back-casting approach where they examine what the resulting demand will be if certain policy targets are met (Ibitoye 2013). LEAP also has compatibility with the Open Source Modelling System (OSeMOSYS) for long-run energy supply optimisation modelling (Howells et al. 2011). Given the aims of this research, this work will focus on LEAP’s demand modelling, and for the residential sector.

LEAP’s energy demand analysis broadly involves hierarchical accounting of annual activity across sectors, subsectors, fuels, and end-use devices with annual intensities of use (i.e. final energy consumed per unit of activity) (Heaps 2008). The model operates either by specifying time-varying data over the model timeline in absolute figures and/or growth rates, or with the use of expressions that incorporate (multi)variable macroeconomic relationships to simulate consumer behaviour (Bhattacharyya 2011). Analysis at the end-use level can be further extended by utilising LEAP’s useful energy demand analysis. This allows the user to independently consider: (i) how useful energy demand is impacted by changes in socio-economic developments over time; (ii) changes in the market penetration of devices; and (iii) changes in the efficiencies of devices (SEI 2012).

Similar to other models and modelling tools, the selection of energy demand sectors modelled in LEAP, the detail of their treatment, and the basis of projections, is typically reflective of the model’s objective. LEAP models analysing future energy supply understandably consider supply to a number of demand sectors; including transport, industry, commercial, and the residential sector. In cases such as this, residential disaggregation is unlikely to go beyond a distinction between urban and rural demand (Kumar et al. 2003),

and can sometimes be treated as one aggregated residential demand (Huang et al. 2011).

In accordance with this limited treatment, the basis of demand projections typically rest on national forecasts made by energy ministries, utilities, or planning agencies (McPherson & Karney 2014, Pervez et al. 2015). Although these models focus on supply dynamics, model calculations would still be dependent on stated levels of consumption in the demand sector(s). Therefore, an implicit or explicit assumption of these models is that the effects of the policies being examined, on future demand structures, have already been accounted for in forecast data being used. Models that focus on the supply of a single resource (primary or secondary), such as electricity, do not account for the influences of non-electric energy on electricity demand (Park et al. 2013), or will have to assume these effects have been accounted for. These limitations are not too critical for supply models developed in LEAP because they concede the uncertainty of the demand-side, and answer what particular approaches to supply would mean (in terms of costs and emissions) for a given progression of demand.

Energy system models developed in LEAP — giving attention to demand and supply — typically also focus on multiple energy demand sectors, but tend to give endogenous treatment to their projections of demand, based on assumptions about key drivers of demand growth; such as GDP and population (Islas et al. 2007). Many of these models seek to examine demand-side policies in addition to those of the supply-side, as they observe what the resulting impacts on carbon emissions will be (Ghanadan & Koomey 2005, Wang et al. 2011, Kemausuor et al. 2015, Wongsapai et al. 2016, Yang et al. 2017). Because the models consider the whole energy system and multiple sectors, the residential sector is rarely disaggregated beyond the urban–rural dichotomy. Energy consumption effects of policies are modelled by specified changes in activity at each level of the model structure, including percentage–use of fuels and technologies. For example, an energy efficiency policy scenario can assume and specify the replacement of low efficiency appliances with high efficiency appliances at given rates annually (Tanatvanit et al. 2003); or a scenario in which energy diversity is led by the public, specifies the proliferation of renewable energy technologies in up to 50 % of households (Ghanadan & Koomey 2005). All these specifications are done in accordance with previously narrated scenario storylines. The model then accounts these scenario changes in LEAP and produces results on aggregate demand and supply, and associated carbon emissions.

In essence, these energy system models inform decision-making by answering one type of question about the future: what will be the result of an energy system pathway if the impacts are as expected, and thus direct what pathway to select. Because these models operate with limited disaggregation, there is less room for obtaining insights about seen and unforeseen consequences of a policy pathway; and what the result might be on the demand structure, supply and emissions.

Demand-focussed models are at more liberty to make greater use of LEAP's bottom-up advantages and demand analysis functions, due to the absence of supply-side modelling, where assumptions about supply possibilities are accounted for in scenario narratives. Since their questions deal directly with the prospects of future demand there is greater desire to break up the urban-rural distinction further, particularly if there is an added modelling boundary to the residential sector alone. Although considering multiple sectors in its assessment of future demand, the Ethiopian government adopted a model which disaggregated the rural sector further to include households connected and not connected to electricity infrastructure (EREDPC 2007). Ibitoye's (2013) LEAP model of the Nigerian residential sector accounted for electrified households in both urban and rural locations, in addition to which of these households live within single or multiple rooms — with single-room households in urban and rural areas serving as proxies for urban-slum and rural-poverty lifestyles respectively.

But with the added focus on demand-side dynamics, still only a few of these models give partial consideration to some of the context-specific features of developing country energy systems that influence consumer behaviour. Modelling the household sector alone, Ibitoye's model utilises LEAP's useful energy analysis to account for impacts in the changing efficiencies of cooking devices, after estimating the annual per capita useful energy for cooking. Incorporating the impacts of power outages, which represent a ubiquitous feature of power systems in many African countries, the model makes assumptions about how electricity availability to those that are connected will develop. This allowed the model to account for the energy stacking behaviour of households that use kerosene for lighting during power outages. However in practice, this is not the only reason households will choose to stack their energy services (see Sections 3.5 or 4.4). The model uses the disaggregation of non-electrified and electrified households as an additional account of changes in the use of kerosene for lighting purposes; since non-electrified households were assumed to use kerosene alone for their lighting purposes.

Thuy & Limmeechokchai (2015) also developed a residential energy demand model in LEAP to explore the implications of alternative climate policy interventions in Thailand and Vietnam; based on either a demand-side management pathway with efficiency improvements to lighting, cooking, refrigeration, and air-conditioning appliances used, versus a pathway that sees an increased use in renewable energy. Due to limited treatment of household energy behaviour and the context in which these energy demand changes occur, their model presents energy savings and carbon emission results based on effective implementation of these policies, and reveals what is most useful for each country with respect to its current state of energy consumption (base level of energy efficiency and fuel mix). There is limited room for policy recommendation beyond this, and the suggestions of which alternative

scenario is better for each country still require examinations around implementation and potential household responses in practice.

Some demand and energy system models developed in LEAP have had objectives centred on energy poverty and access, and this influenced the structure and scope of the model. Limmeechokchai & Chawana (2007) developed a model exploring the impacts of ICS and small biogas digesters (SBD) on household cooking energy demand and resulting emissions in Thailand. They structured the household sector according to subsector categories for Greater Bangkok, municipal areas, and rural areas of the country. Further disaggregation provided a distinction between electrified and non-electrified households, which would allow the model to consider the influence of electricity availability on electric and non-electric cooking behaviour. One area of modelling change is therefore through differences in the percentage distribution of households in the three regions and between the electrified and non-electrified. The model received specified energy consumption intensities for all end-use devices based on usage time per year, the power capacity of the device or energy consumption per batch of stove type, and the number of the devices per household. These energy consumption intensities are assumed to be the same in all subsector regions of Thailand, which presents a possible limitation of the model; but it attempts to accommodate for this in differences between penetration rates of end-use appliances across the three subsector regions. While this presents a partial solution to capturing differences between the behaviour of households in greater Bangkok, municipal, and rural areas of Thailand, it misrepresents the nature of change in multiple energy service use that households experience over time as they introduce and transition to the use of new services. A rural household is unlikely to make use of a gas stove in the same manner a greater Bangkok household would, even if they were both unelectrified; considerations of proximity to access for the energy carrier, technology, support services, and other cooking energy options would have an impact on behaviour.

Further, because the model makes its specifications of future scenario outcomes based on the assumption that existing policies can achieve their intended outcomes (and making abstract strategic recommendations in doing so), it characterises most of the future energy transitions to reach complete energy substitution, and measures emissions savings based on this. Similar to some of the LEAP models discussed earlier, the model does not aim to account for potential failures in the market brought about by unintended consequences of these policies. But importantly, the study concludes that there is a high potential to reduce consumption and emissions by ICS and SBD adoption, and measures the cost-benefit of doing this. If there is a longer period of stacking in practice than the model accounted for, then the cost-benefit profile can prove to be very different.

Ouedraogo (2017) produced a LEAP model to explore future energy demand and as-

sociated carbon emissions in the continent of Africa, in light of the global goal to achieve universal energy access amidst related renewable energy and energy efficiency goals. The model organised its scenarios in order to shed light on potential synergies or trade-offs between energy access and tackling climate change. In modelling such as this, it is all the more important to be mindful of how the model captures the social–energy dynamic; as highlighted above. Since the model considers a range of sectors it is understandable that its household disaggregation is limited to the urban–rural distinction. The model’s main scenario variables include population, economic growth, structural change, energy efficiency improvements, and renewable fuel switching. The latter component of the model, fuel switching, can lead to overestimation of emissions savings, given the possibility of energy stacking.

Mustonen (2010) developed a model at the scale of a rural village — Nam Kha, in Laos — with a disaggregation that distinguished between consumers that will, and will not, connect to an off-grid electricity supply; from the household, small industry, public institution, and commercial sectors of the village. A particular benefit of this model is the fact that it was based on a village that was in the process of being electrified, and therefore could rely on data pre-electrification and post-electrification, after the first year of the mini-grid operation. Future pathways following this, were specified to explore the possible energy demand that different approaches to electrification might induce in the village. LEAP was predominantly used for accounting, as energy demand projections were based on narratives of expected socio-economic developments under each scenario, based on the sectors chosen in the electrification strategy. When considering transition pathways, the model accounted for a small continued presence of kerosene and paraffin use in the event of power cuts, but did not consider instances of energy stacking (in the form of simultaneous use) outside of interrupted power cuts; which households are known to undertake. For example, the number and positioning of light bulbs in newly electrified households may not be able to displace the previous mobile use of some kerosene lanterns (further discussion in Chapter 7). But the focus of the model — which used its scenario narratives to question the impacts and knock-on effects of energy transitions, from the possible future demand–supply balance and resulting financial viability, along with the potential for income generation and its impact on energy demand/affordability — presents another way of using LEAP, which is to use the scenario narrative to inform strategy behind a particular policy or course of action.

What the models reviewed above have shown are some shortcomings in accounting for some of the energy behaviours that are typical of, and significant to household energy service transitions in developing countries; such as energy stacking. There are also shortcomings in fully accounting for the drivers of energy behaviour; where it is often assumed that change in the fuel–technology combination used for a particular energy service (e.g. cooking) is



independent of change in the fuel–technology combination of other energy services (e.g. lighting). Whereas in reality, the energy–behaviour change is dynamic; including synergies and trade-offs with respect to a number of internal and external household factors (see end of Section 3.6.1 and discussions in Chapter 4). The usefulness and importance of accounting for these features is because it is in these cross-service/fuel/technology interactions that the knock-on effects of energy service change, and the unintended consequences of energy policies and strategies can be revealed. Models that rely on LEAP’s useful energy analysis will find difficulty in incorporating a holistic treatment because the approach segregates the modelling of different energy services. The Lagos–LEAP model adopts a modelling approach that attempts to account for these features of household behaviour change.

It is worth remembering that the extent to which LEAP’s bottom-up modelling capabilities can be used is dependent on the availability of quality energy, social, and economic data. Therefore, the model structures adopted by the studies reviewed may well have been dictated by the data available. There is a need for state and national energy data collection authorities in developing countries to adopt methods that are sensitive to the energy stacking behaviour of households, in order to support analyses. Global efforts are underway to tailor energy data collection methods, to better support how we measure progress towards universal energy access (see Bhatia & Angelou 2015). Similar efforts on data to support planning and decision-making will be useful.

While this short review of models developed in LEAP has identified areas in which insights are unavailable, this is largely influenced by the objectives of the models created. In LEAP models of energy demand, the aim has often been to explore the demand and emissions impacts of selected energy policies; where the alternative scenarios are designed to present the expected future consequences of a particular policy vis-à-vis the reference scenario. This allows the study to inform decisions about pathway *selection*; because what the model may lack in detail (e.g. the practice of energy stacking), it makes up for in consistency across the modelled scenarios. Thus, potential cost-benefit overestimations highlighted earlier would be of reduced consequence in the context of selecting a preferred option. But this does not help inform policy or strategy implementation considerations because the unintended consequences of a pathway cannot be revealed; and this is an area in which energy access decision-makers require further support from scenario exercises. One way of doing this, is to design alternative scenarios to capture differing social, institutional and market futures, or differing *external environments* in which energy decisions are made (see Chapter 4; and allowing the model results to provide energy policy/strategy insights as it depicts the progression of energy demand across the scenarios. LEAP’s flexibility and bottom-up modelling capabilities mean that it is the most suitable tool by which this can be achieved. The next section will discuss how this can be done by introducing the original modelling

concept and scenarios explored in the LEAP model developed for Lagos' households.

### 5.4.3 The Lagos–LEAP household energy demand model

The Lagos–LEAP household energy demand model and its use to answer research question 3 is distinct from the classic LEAP energy demand model in two ways: its model structure, and its use of scenarios. These differences impact the manner in which data inputs to the model are undertaken, and how the model results are analysed.

Firstly, the Lagos–LEAP hierarchical structure is disaggregated such that each branch denotes a form of energy accessibility resulting from a particular organisation of daily life. Chapter 4 discussed how a person's/household's organisation of daily life had an impact on their energy service decision-making; where their external and personal contexts shape their daily activities to influence their access (affordability and availability) to energy services (see Sections 4.3 and 4.4). While this model will be restricted in the indicators considered, due to practical limitations of modelling and data availability, it is designed such that demographic subcategories at each level of the hierarchical structure denote a contextual situation that influences a household's energy accessibility.<sup>9</sup> The hierarchical structure incorporated subcategories around settlement, income, reticulated electricity supply, private electricity generation, and technological profile as indicators of a household's organisation of daily life. The lowest level of the model structure is then used to attribute all the various types of energy behaviours possible, in view of the subcategories that make up each branch (see Figure 5.3). Structuring the model this way makes it possible to account for some important features that surround household energy decision-making. These include: (i) taking a holistic approach to the technology, fuel, and energy service behaviour of a household by treating all dimensions of a household's energy use as one *energy service profile*, which allows the model to account for cross-service interactions that influence behaviour; and (ii) accounting for the practice of load shedding, its relationship with private electricity generation, and their combined impact on household energy behaviour — all of which are features of many developing country power sectors, including Nigeria's.

Secondly, the scenarios modelled consider alternative pathways in the social, institutional and market drivers (external environment) that influence a household's organisation of daily life, and thus their energy service use (or prespecified energy consumption intensity; see Figure 5.4). Designing scenarios according to social, political and economic development is not new, and has been adopted in models of environmental sustainability and national development (see Mont Fleur scenario exercise in Jager et al. 2008, p. 7); where there is a

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<sup>9</sup>Since disaggregated modelling of households in a given region is based on groups and subgroups (for which data is available) of households that are assumed to share similar characteristics, there is a natural limit to which factors influencing energy behaviour can be considered. For example, differences observed at an individual level and pertaining to the more psychological drivers of behaviour such as personal habits, experiences and predispositions will not be accounted for. But these are factors which the more qualitative first phase of the research method explores.

**Figure 5.3:** Lagos–LEAP model disaggregation

Sector	Level 1		Level 2		Level 3		Level 4		Final Energy Analysis
	Settlement	Income classification		Availability of reticulated electricity		Energy consumption efficiency			
	Urban - NonSlum Urban - Slum Rural	High Medium Low Poor		Base High		Base Efficient			
Residential	HOUSEHOLD ENERGY SERVICE PROFILE			definition for each Ret_E availability group differs between settlements (urban, rural, slum)					
		Level 5		Level 6		Level 7		Final Energy Intensity	Activity Parameters
		Energy service Category		Conversion Technology		Primary/Secondary Fuels			
		Lighting		23 technologies across all energy services		Reticulated electricity (Centralized and Decentralized)			
		Cooking				LPG			
		Refrigeration				Wood			
		Water heating		(e.g. fan, solar lantern etc)		Kerosene			
		Water pumping				Petrol			
		Space cooling				Diesel			
		Clothes washing				Solar			
Other appliances									

Source: Author's depiction

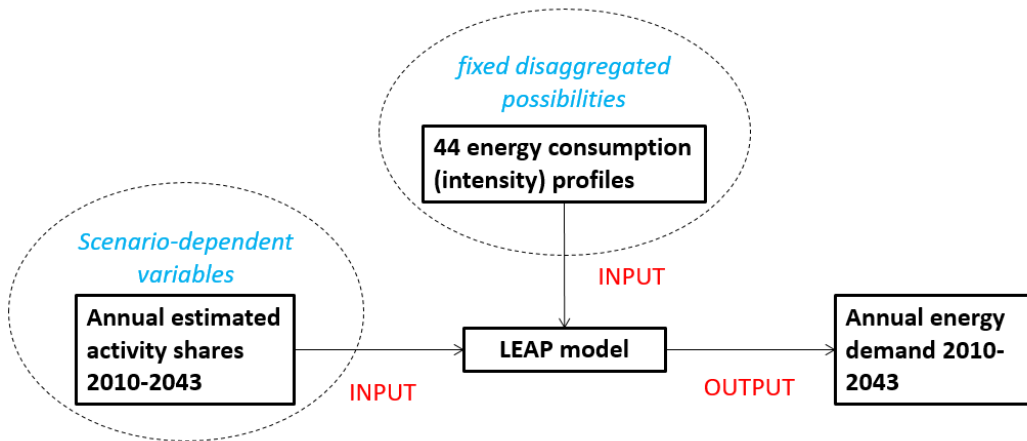
Note: Private electricity generation differs according to income group, but responds to the availability of reticulated electricity and therefore also differs according to settlement.

desire to paint pictures about plausible future developments in society. This is less so with energy system models; and as discussed earlier — is not the approach of most LEAP energy demand models.

The Lagos–LEAP model, and scenarios explored with it, are *not* designed to determine the most suitable pathway for social and economic development in the state for fostering favourable household energy transitions, since preferable developmental pathways will be evident from the stated developments for drivers in each scenario. Instead, they are designed to reveal possible developments in household energy transitions, from which, insights about policy and strategy can be drawn. In this the model is distinct from models of environmental sustainability which sometimes use scenarios as a basis for assessing the influence of social and economic drivers on future emissions (Nakicenovic & Swart 2000). Whereas for Lagos–LEAP, the partial influence of each scenario driver on the model structure is exogenously treated (not considered an output of the model); where the annual influence of all drivers on the model structure for a given scenario are inputs to the model as estimated activity (proportion of households in a particular subcategory at each level of the hierarchy) at each level of the model structure over the timeline of the model. The product of the fixed energy consumption intensities (denoting a particular organisation of daily life at the end of each branch in the hierarchical structure) and annual changes in the percentage distribution of households across the model structure is then accounted by LEAP to produce annual changes in energy demand (see Figure 5.4). The nature of change in energy demand over the model timeline is then analysed to reveal insights. This makes the model outputs very responsive to its structure and assumptions, and these are presented in detail in Chapter 8.

This approach to modelling in the Lagos–LEAP means that some of the evidence-based intricacies of household energy behaviour can be pre-specified in accordance with contexts

**Figure 5.4:** Schematic of Lagos-LEAP inputs and outputs



Source: Author's depiction

that drive them. By having more diversified groups of households with particular energy behaviours according to their contextual circumstances, a more dynamic shift in energy use can be modelled with changing circumstances when households are moved from one group to another. For example, a household with the energy accessibility of a rural household will vary in energy behaviour from those with the accessibility of urban or slum households; it will experience further variability in its energy accessibility, and thus energy behaviour, depending on the income group it belongs to; and further behaviour variability given the group it belongs to regarding reticulated electricity supply; there is further variation in accordance with the group it is in according to its need and capacity for private electricity generation; and further still, variation depending on the efficiency of the household's technological profile. In models with less disaggregation, energy behaviour can only take on two, three or four conditions over the model timeline depending on the number of future assumptions for fuel and technology use per household group that are introduced over the model timeline. But in Lagos-LEAP, 44 household energy profiles are available for explaining the manner in which households can engage with energy over Lagos-LEAP's modelling timeline from 2010–2043. Within these profiles, there are 376 ways in which 23 energy technologies can be used.

Furthermore, in other models the options for change in energy behaviour will affect different energy services independently of one another. Whereas in Lagos-LEAP, the use of energy profiles means the pre-specified usage of all household technologies for a particular group has considered the cross-service impacts, in accordance with the data available and transparent treatment of assumptions. For example, developments in the use of a modern fuel (such as electricity) for lighting with consequent changes in the use of kerosene for

lighting, can also have an impact on kerosene for cooking, and thus knock-on effects for other fuel–technology combinations for cooking — both traditional and modern. The difference in the latter effect can also be dependent on and captured in the income classification level. Right throughout the structure of the model, at each level, these incremental effects have been considered and contribute to the final energy profiles in each of the 44 branches. Appendix C provides the data treatment for each branch in the model, and the rationale behind them.

In developing the 44 sets of possible energy consumption profiles a Lagos household can exhibit over the model timeline, changes in behaviour by virtue of new introductions in fuel/technology options for existing and new energy services — made possible by new energy supply capabilities over time — have also been considered. These were incorporated particularly through subcategories in the reticulated electricity supply, and technological profile levels of the model structure. Therefore, the branches of the model pertain to current and alternative future household energy demand profiles in Lagos state. Secondary data sources of energy demand and supply were used to create a database with pre-calculated annual energy consumption intensities in kilowatt–hours for each branch (*disaggregated energy consumption intensity*), according to attributes including: average daily supply of reticulated electricity (hours); average daily supply of privately generated electricity; the *useful* annual energy demand of an appliance to fulfil an energy service (kWh); types of appliances operated and associated power consumption; percentage use of an appliance in relation to its energy service’s useful demand, to identify *actual* consumption behaviour; and number of appliances per household (see Appendix C for further details). Further discussion on key data, sources, and assumptions in the development of the model database is provided in Chapter 8.

The model operates like this: In the model’s base year (2010) each household is characterised by a particular profile of energy demand, by virtue of their subcategory at each level of the model structure and their resulting branch. At this point some branches will have no households associated with that form of energy use by virtue of the subcategories that make up the branch (e.g. branches associated with a subcategory capturing future increases in hourly electricity supply, which develops further down the model timeline), but this is then subject to change over the model timeline. The scenario drivers — which are discussed in Chapter 8 — drive annual changes in the proportions of households across the subcategories at each level of the model structure till the model end–year, in accordance with the narrative of each scenario. Inputting these household percentage distribution changes in LEAP and running the model, provides results on the nature of change in household energy demand per year till the model end–year (2043).

An important concept of the Lagos–LEAP model is the interpretation of what shifts

in subcategories at each level of the model hierarchy represent. The model makes use of indicators pertaining to a household's social and economic status to categorise and disaggregate all households (settlement, income, etc.) suggesting that shifts in the percentage of households across subcategories at a particular level denote changes in the absolute status of households. For example, an annual increase in the share of households categorised as having high income suggests an increase in household incomes such that there is a greater number of households in the high-income bracket of the state. While this is an appropriate way to interpret such a change in this model, it is not the only way in which such changes should be considered. The model places emphasis on illustrating the organisation of daily life leading to changes in energy demand. Therefore, just as in reality a household's accessibility to an energy service can increase — without necessarily a change to its income — because the service has become more affordable through price decreases, or flexible payment options, so too does the model interpret that such a shift in households categorised in the high income subcategory can arise from these changes, and not specifically changes in income. The interpretation here is that, accessibility brought about by changes in the household's organisation of daily life has led to energy behaviour similar to that of households with naturally higher affordability.

Acknowledging this, is important in appreciating how the scenario drivers are considered to influence changes in household shares, and the insights that can be gleaned from analysis of resulting energy demand. The model does not treat some supply aspects such as price signals endogenously, but they form part of scenario narratives and are considered to influence the model in such a manner. Since the model structure is highly disaggregated, the extent to which such capability changes might overstate or understate overall energy behaviour is limited. For example, the overall energy service behaviour of a lower-income household obtaining (transitioning to) higher-income subcategory access through favourable conditions for accessibility, may still differ to that of other households in the higher-income subcategory depending, for example, on the amount of electricity made available to it per day, among others; differences that are captured at other levels of the model structure, and are subject to changes in scenario conditions that drive shifts in those levels. Other interpretations surrounding the changes in percentage distribution of households are further discussed in Chapter 8.

### ***Lagos-LEAP scenarios***

In this work, the term “scenario” captures a narrative developmental pathway for Lagos state and Nigeria, which is quantified through selected indicators to estimate and model changes in the household energy service behaviour in Lagos state. The approach draws on scenario development methodology detailed by research and institutions that have been at

the forefront of futures studies (Schwartz 1991, Jager et al. 2008, UNEP 2004) in its use of scenario drivers and its linkage between narratives and indicators. As mentioned at the beginning of Section 5.4, scenarios used for futures planning tend to adopt a participatory process in their development; whereas those developed in academic applications can be a lot less interactive. A participatory process makes it possible to engage with necessary stakeholders in the formulation of key forces and sources of uncertainty influencing the environment of the focal issue (Jager et al. 2008). Such a process was not necessary in this research however, because the key forces of uncertainty adopted stemmed from an appreciation of household energy service dynamics identified in theory (Chapter 4), and later refined to be specific to Nigeria and Lagos using information coming out of Chapters 6 and 7 (see end of Section 5.2.1). Nevertheless, stakeholder interviews and meetings were undertaken to support the development of the model database and the scenarios; in the case of the latter, this was in order to set boundaries around selected forces by exploring a range of views on the future of the state and the country. Details of these meetings can be found in Table 5.3.

The purpose of the scenarios is to provide coherent and reasonable storylines about social and economic development in Nigeria and Lagos. All scenarios developed in the model (including the reference scenario) should not be considered forecasts, as they are founded on assumptions made about future conditions in the state — some of which are unlikely to become reality over the model timeline. A reference scenario is narrated based on current developmental trends. Three alternative scenarios narrate pathways for development based on the role of the state and private sector in energy access and development. As discussed in Chapter 3, the activities of both the public and private sector have an important impact on the success of energy access interventions (see Section 3.4.1). The role played by these key stakeholders in shaping energy access and wider societal development, impact the nature and pace of growth. It is generally accepted that some level of private and state involvement is necessary for inclusive and sustainable development (Commission on Growth and Development 2008, Lin 2012), and this will represent the storyline for one of the scenarios: the Hybrid scenario (HYB). The other two scenarios will respectively present storylines where development is dominantly reliant on either the private sector — the Private Sector scenario (PRI); or the state — the State scenario (STA). The scenarios are discussed further in Chapter 8, which will elaborate on the representation of external environments in each scenario.

**Table 5.3:** Stakeholder consultations during fieldwork

Organisation	Description	Location and date
<i>Energy companies</i>		
Eko Power Distribution Company	Meeting with Senior staff of one of the two successor distribution companies in the state of the former PHCN	Lagos, November 2013
Ikeja Power Distribution Company	Meeting with Senior staff of one of the two successor distribution companies in the state of the former PHCN	Lagos, November 2013
Siemens Nigeria	Major participant in the Nigerian energy sector development with the provision of products and services	Lagos, November 2013
<i>Government</i>		
Lagos State Ministry of Energy and Mineral Resources	Meetings with Senior advisors of the Energy Minister	Lagos, September 2013
Lagos State Electricity Board (LSEB)	Meeting with the Managing Director of the state project implementing agency	Lagos, September 2013
Lagos State Ministry of Housing	Meeting with planning staff on housing plans within the state	Lagos, November 2013
Lagos Metropolitan Area Transport Authority (LAMATA)	Meeting with Senior staff on transportation plans of the state	Lagos, November 2013
<i>Academic</i>		
National Centre for Energy Efficiency and Conservation (NCEEC)	Meeting with Director of one of the Energy Commission of Nigeria's (ECN) research centres, based at the University of Lagos	Lagos, November 2013
<i>Multilateral organisations</i>		
UNDP Energy Efficiency Programme	Conversation with the programme manager of the UN sponsored programme on the end-use technology trends in Nigeria	Telephone, October 2013
International Finance Corporation (IFC)	Meeting with Senior staff of IFC's Lighting Africa team on the institution's plans for Nigeria	Lagos, November 2013
Bank of Industry (BOI)	Meeting with staff at the BOI on the investment focus of the institution for Nigeria's energy sector	Lagos, November 2013
<i>Other research</i>		
Market Trends International	Meeting with Senior staff on the trends seen in the downstream energy sector in Nigeria and Lagos	Lagos, November 2013
International Centre for Energy, Environment and Development (ICEED)	Meeting with Senior staff on the trends seen in household technology use in Nigeria	Lagos, November 2013



## 5.5 Conclusion

This chapter has discussed the pragmatic methodology adopted in this research. The case of Lagos was selected for a range of reasons, including the aim of addressing some of the methodological gaps observed in the field, the requirements of research questions 2 and 3, and the feasibility of conducting cross-cultural research. Some of the key aspects of conducting fieldwork across cultures were considered and proved to be important areas of consideration to ensure a successful time in the field; given its challenging nature and unpredictability. In this qualitative strand of the research it was necessary to structure time spent in the field in stages to aid identification, refining, and verification of themes and insights; where semi-structured interviews served as the dominant method for obtaining a rich set of data that is useful for learning about household behaviour. The chapter also critiqued models of developing country household energy demand; highlighting the need for approaches that can capture aspects of household energy transitions to inform policies and strategy that give greater consideration to their unintended consequences. The Lagos-LEAP model has been developed to account for some of these aspects as it seeks to answer research question 3, with innovation in its model structure and its use of scenarios.

The chapter that follows will provide a detailed description of the case contexts at the state and national level, as they relate to household behaviour at the local level; and a rich description of the communities in rural Lagos selected for fieldwork is provided, before Chapters 7 and 8 discuss the answers to research questions 2 and 3 respectively.



## Chapter 6

# The Case Study External Environment: An Overview of Epe, Lagos and Nigeria

*What is the external environment influencing the energy decisions of Lagos state's households; and specifically, that of households in the case study region?*

## 6.1 Introduction

The previous chapter introduced Lagos, Nigeria as the selected case with which research questions 2 and 3 will be answered. These questions have, at their foundation, an appreciation that household energy services are shaped by interactions at multiple levels of society; and question 2 seeks to explore the evidence at the local level that can explain the dynamics of these interactions, while question 3 examines the household energy demand implications of possible future developments at the external (micro to macro) level. In order to investigate and answer these two questions, an appreciation of this external environment influencing the energy decisions of Lagos state's households is necessary. Van Der Kroon et al.'s (2013) framework, discussed in Chapter 4, provides some of the attributes that must be considered (see Figure 4.4). The external drivers of household energy choices can be grouped into the factors that make up the *socio-cultural and natural environment* and those that make up the *political-institutional-market environment*. The former includes a region's history, geographical location, and ecology; the latter includes government policies, technological markets, labour markets, capital markets, consumer goods market, security markets, and a region's social environment. This chapter will review the state of these forces for Lagos and Nigeria, at the time of this research's undertaking. It will also provide a detailed description of the communities included for primary data collection in the field.

The discussions presented in this chapter stem from an extensive review of a wide range of documents on the sector — including white papers, legislation, newspaper articles, sector reports, and academic resources — in addition to stakeholder consultations during fieldwork. Section 6.2 will introduce twenty-first century Nigeria; using an overview of its post-independence history to illustrate its cultural, societal, and economic development. Section 6.3 will review the areas that make up Lagos and Nigeria's political-institutional-market environment. Section 6.4 details the context of the case-study region researched during fieldwork; before Section 6.5 concludes the chapter.

## 6.2 Endowments and development history

The Federal Republic of Nigeria is situated in West Africa; bordered by Niger in the north, Cameroon in the east, Benin and the Gulf of Guinea, in the west and south respectively (see Figure 6.1). With a population of over 185 million people (2016 figure) situated on the country's southern rain forest vegetation and northern savannahs (World Bank 2016b), it is Africa's most populous nation. Nigeria has the largest oil and gas resources in Africa, with the ninth largest proven gas reserves worldwide (EIA 2016). The country also holds considerable renewable energy resources; which are most prevalent in the northern regions, in the form of wind, solar, hydro and biomass resources (FGN 2015).

The country is organised as a federal constitutional republic, with 36 states and a fed-

Figure 6.1: Map of Nigeria



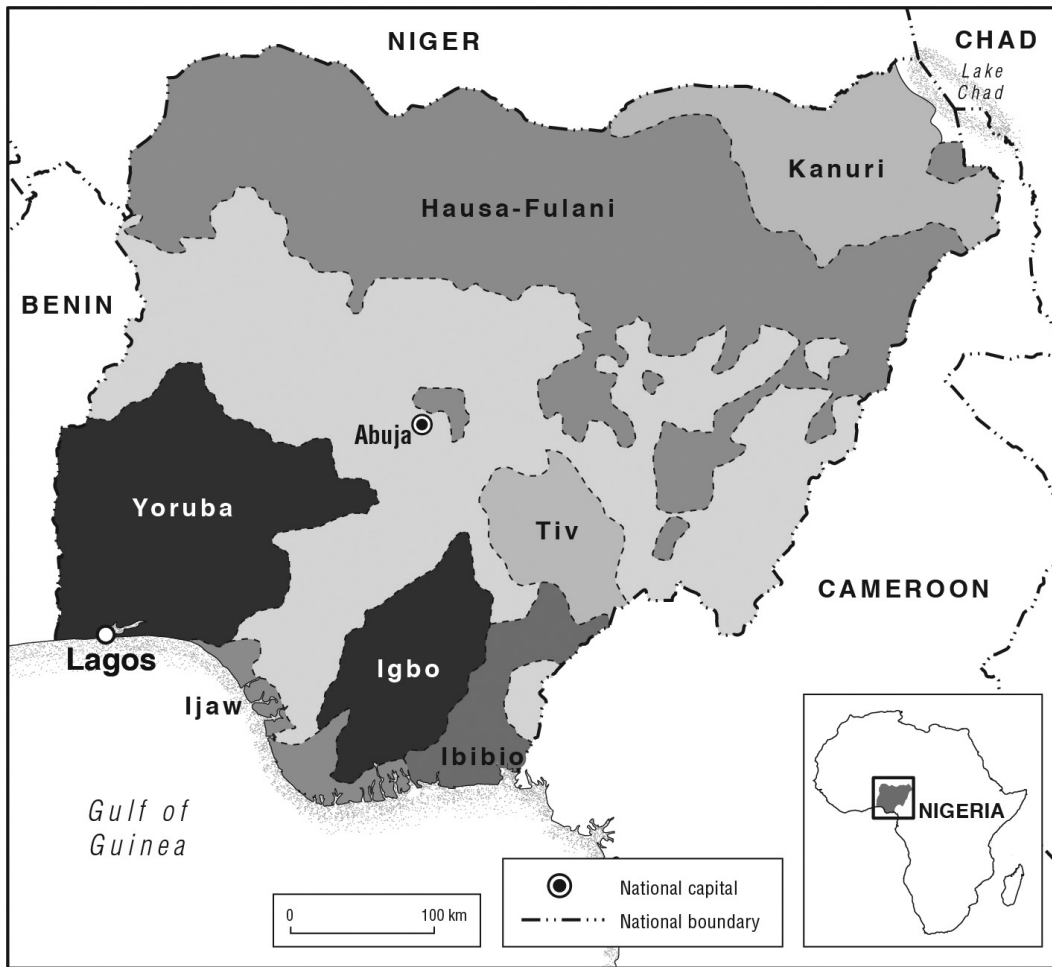
Source: UN (2014)

eral capital territory, Abuja (FGN 1999). There is a high level of ethnic diversity amongst its population with over 250 ethnic groups and languages. However, its geopolitical sphere is largely formed around the country's four major tribes; the Hausa–fulanis, Yorubas, Igbo, and Ijaws in the north, south–west, south–east and south–south areas of the country respectively (see Figure 6.2).

Following the 2010 rebasing of Nigeria's economic data, its gross domestic product (GDP) is estimated to be the largest in Africa, with 2013 data revealing a GDP of \$510 billion (2013 international dollars) (Leke et al. 2014). Although the country's productive sectors are more diversified than previously thought — with only 14 % of GDP from the resources sector (NBS 2013, Leke et al. 2014) — an indicator of Nigeria's dependence on its petroleum sector can be seen in its share of total exports (95 %), and federal revenues (75 %) (World Bank 2013). With a history of oil revenues being used to fund petroleum import subsidies, little has been done to channel resources to spur inclusive development; leading to a dearth of institutional capacity, infrastructure, and services required for an efficiently functioning society (Ploeg 2011).

Although Nigeria's human development index has been increasing over the past decade,

**Figure 6.2:** Nigeria's main ethnic groups



Source: Adapted from Leke et al. (2014)

it still ranks a low 152 out of 188 countries and territories (UNDP 2015). Life expectancy is lower than the SSA average at 52.8 years, latest figures on youth literacy puts the country share at just 72.8%, and half of the country's population is multi-dimensionally poor (UNDP 2015, 2016, World Bank 2016c). Problems due to a history of corruption and bureaucracy that have hindered productivity have also resulted in a large proportion of the country's wealth being concentrated in the hands of an elite minority, in addition to uneven growth across regions of the country (Smith 2007).

The absence of equity and inclusive development in the country is a symptom of long-standing governance challenges in Nigeria since its independence in 1960, fuelled largely by ethnic and religious divisions. Despite the country's endowments, this factional struggle for power between geopolitical regions of the country has hindered its development, with inefficiencies at every key enabler of growth, including its energy sector. The section below provides a brief overview of the country's short history, illustrating the culture of governance

that must be addressed for the country's development targets to be achieved.

### **6.2.1 A country crippled by corruption**

#### ***Liberated but divided***

By the time Nigeria gained independence from British colonial rule in 1960, its federal apparatus was fragile with divisions at many levels (Anugwom 2000). The amalgamation of previously independent states for commercial necessity by the British during colonial rule was the very fabric that served to divide the politically independent country (Akpeninor 2013). The ethnic and religious disparities between major zones in the country encouraged regionalism and tribalism, hampering the development of a true national identity (Akwara et al. 2013).

Exacerbating the implications of a divided polity was the post-independence reality that the country remained economically dependent on European firms in the ownership and operation of local industry and the export economy, along with the discovery of proven petroleum reserves just prior to independence (Adeyeri & Adejuwon 2012). In contrast to the leadership shown by Botswana's first president, Sir Seretse Khama, who convinced all clan chiefs to unite the country in its ownership of newly discovered diamond resources (Collier 2013), the Nigerian ruling class' management of petroleum resources served to lead the country down a path of corruption, underdevelopment, poverty, environmental pollution, and human rights violations.

Ten years after independence Nigeria was subjected to military rule. It had experienced two coups — the first of which killed the country's prime minister at independence (the First Republic) — and a two and a half year civil war that took the lives of millions of Nigerians (Jauhari 2011); the ramifications of which have left Nigeria on the brink of separation ever since. In the aftermath of the war in 1970, economic growth resulting from a revitalised petroleum sector failed to bring about development but instead brought about two decades of increased corruption, debt, bureaucracy, and a neglect of the people (Falola & Heaton 2008). By the time a shift to democratic rule was reattempted, access to state power had become so lucrative that coups, annulled election results, mismanagement and embezzlement of public funds had become the norm (Ogbeidi 2012).

#### ***Economic turmoil***

By the mid-1990s, a small group of the political elite and their acquaintances had become exceedingly wealthy from the oil sector, while the majority of the population lived in poverty. Despite a wealth of oil reserves, which had now been in production for decades, the country was ridden with debt, and was heavily reliant on oil exports (Rieffel 2005). The wealth provided by the petroleum sector, also brought about a long-standing disconnect between those in power and the will of the people (Falola & Heaton 2008).

Nigeria had become a prime example of a country exhibiting the “Dutch disease”.<sup>1</sup> Following the oil boom beginning in the mid-1970s, brought about by high oil prices resulting from the OPEC embargo; investment in the Nigerian petroleum sector grew as did revenues to the state, along with domestic demand for imported goods. Agriculture and manufacturing suffered extensively, as utilization of the latter fell from a high of 78.7% in 1978 to 38% in 1986 (Falola & Heaton 2008). By the time oil prices crashed in the early 1980s, Nigeria’s economy suffered, its external debt skyrocketed, as inflation rose to levels between 30% and 50% (Budina et al. 2007, Falola & Heaton 2008).

When the country’s debt reached critical levels, it was forced to accept a Structural Adjustment Programme (SAP) in 1986, that involved among others; the abolition of price controls, privatisation, currency devaluation, and major reductions in public spending (Leke et al. 2014). This kick-started a period of wealth loss in the country, the purchasing power of the average Nigerian fell dramatically over a decade, and has never recovered. From currency parity with the dollar in 1985, the naira fell to ₦22 against the dollar by 1994 (Falola & Heaton 2008). As at December 2016, the naira officially traded around ₦305 to the dollar (CBN 2016), and circa ₦490 on the parallel markets. As the population grew, income levels fell, and the prices of most imported basic necessities could no longer be controlled; people struggled to afford food, health care, fuel, and education (Falola & Heaton 2008).

### ***Societal dysfunction***

The system implemented in the early 1970s for oil revenue distribution across the country encouraged dishonesty and suppressed capacity building in data collection and management processes; as it favoured states with larger populations or indeed, states that propped up their population figures (Ikeji 2011). Public administrative capacity — which remains low (Ugwuegbu 2011, Dibie 2018) — was depressed by longstanding corruption and the early misguided prescriptions for alleviating the country of it.<sup>2</sup> Civil service and government administration moved from constituting a bloated, highly-paid, inefficient workforce, to one that was unmotivated, and inconsistently remunerated (Falola & Heaton 2008).

The result has been a spate of inadequacy and mediocrity that has become part of everyday life in Nigeria, such that it can be argued to be part of the country’s culture (Achebe 1984). Efficiency has been sacrificed at the expense of petty corruption at various levels of society. Increasing levels of poverty during austerity periods of the 1980s saw people

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<sup>1</sup>The Dutch disease refers to the decline in a country’s non-resource exports, resulting from a sudden rise in the value of its natural resources which brings about an uncompetitive real exchange rate (Humphreys et al. 2007).

<sup>2</sup>The military regimes of — later democratically-elected heads of state — President Obasanjo and President Buhari, both made failed attempts to tackle corruption in Nigeria. The former’s regime (1976–79) continued the policy of making wholesale changes to public personnel started by his predecessor; from military governors to civil service, universities, police and the judiciary. The latter’s military rule (1984–85) adopted an authoritarian approach to alleviating corruption with heavy-handed policing of the state (Falola & Heaton 2008).



turn to various forms of criminal activity in the face of weak state capacity to set and enforce the rule of law (Lewis 2006). The sense of injustice and desperation that the public endured gave rise to a diverse set of civil society organizations, which in some cases led to violent sects that continue to plague society and national development today.<sup>3</sup>

By the turn of the millennium, three decades of corruption in the rentier state, either through outright looting or in the award of public procurement contracts, had resulted in poor quality or ill-maintained infrastructure and services that quickly became dilapidated and/or inefficient (Udeze 2009). The country's electricity capacity utilization rates have averaged below 40 % for over three decades, and about 32 % of its population lack access to adequate water services (Eberhard et al. 2016, World Bank 2016*d*). These critical services for societal development suffered further as skilled professionals such as doctors, lawyers, and engineers left the country in search of stable employment overseas, following decades of economic decline (Falola & Heaton 2008, Adefusika 2010).

The lack of public confidence in these services has meant that people have grown to rely on alternatives at a premium. Much of the public, particularly the poor, place greater faith in traditional medicine and spiritual healing given the poor state of public hospitals (Chukwuma et al. 2015). Those who can afford it, seek to meet their health needs outside the country, including politicians mandated to improve the country's health services (Okoro 2009). Industry, commercial and residential sectors are heavily reliant on private diesel and petrol generators for their electricity needs. Most states in the country have poor provision of reticulated water supply, as people are forced to operate private boreholes, rely heavily on bottled water, and other private water supply arrangements at higher prices.

As the breakdown in service provision became so entrenched in everyday lives, the above dysfunctional systems became normal. As people adapted to poor services, the pressure on the government to fix broken systems became negligible (Sandbakken 2006). Instead, the government maintained low taxes as a trade-off for services not rendered, and provided large subsidies on imported basic amenities, such as petroleum products, to offset a lack of equitable growth.

### ***Growth with the handbrake on***

Since the return to democratic rule in 1999, Nigeria embarked on a series of reforms to stabilise its economy following turbulent and slow growth during the 80s and the 90s, when fluctuations in oil prices had greater impacts on its budget and economy (Okonjo-Iweala & Osafo-Kwaako 2007). Figures have shown that Nigeria's economy grew at an average of 8.6 % between 2000 and 2010, and more recently at an average of 5.4 % in 2013 (Leke

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<sup>3</sup>The terrorist activities of Boko haram in the north of the country received wide coverage on global news platforms. Other violent sects have plagued the country's oil & gas industry, such as the Movement for the Emancipation of the Niger Delta (MEND), and more recently, the Niger Delta Avengers.

et al. 2014, World Bank 2015*d*). Its growth has largely been driven by its non-oil sectors; particularly services (Leke et al. 2014). However given the size of growth in the country's population, GDP growth has failed to have a notable impact on poverty levels amongst its rapidly growing population; as per capita GDP trails most other emerging countries (Leke et al. 2014). Between 2006 and 2011, unemployment grew speedily from 12.3 % to 23.9 % of the total labour force, as poor infrastructure continued to impact productivity and the cost of doing business in the country (NBS 2012, World Bank 2012*b*). In addition, low growth in agriculture over the years has been a symptom of few opportunities for smallholder farmers to adopt agricultural best practices, further exacerbating rural poverty (Jake 2011). The result has been a high level of inequality within cities and across the country; as the country's rebasing exercise revealed that 90 % of cash transactions take place in just 7 of the country's 36 states (Ogunlesi 2014).

Nigeria has a young and growing population that represent a high potential for growth in human capacity (UN 2015). However if adequate training and job opportunities are not made available, this potential serves as a pathway to increased poverty as opposed to prosperity. The country's dependence on the petroleum sector for export and federal revenues has reached critical levels, as profitable development of unconventional oil and gas resources continue to suppress oil prices compared to pre-2015 levels (IEA 2015). The opportunity to diversify and develop Nigerian industry to take advantage of a currency exchange rate that favours a trade surplus has failed to materialize, owing to unfavourable investment conditions due to a number of issues. One of these issues has been the inability for the national energy sector to represent the bedrock upon which economic growth and welfare can be realised.

### 6.2.2 Lagos

Lagos epitomises much of the societal and cultural characteristics that best describe Nigeria, but itself holds a unique history and environment that have led to the megacity it is today. It is a Southwest coastal state of Nigeria off the Atlantic Ocean, which has grown over the past half a century to become one of the most populous states in the country, though it has the smallest geographical coverage of 3577 km<sup>2</sup> (LBS 2012). Its strategic location has made it an important intersection for cross-border and overseas trade since colonial rule, and it has grown to become a major port city; with a GDP that is estimated to represent 22 % of Nigeria's economy (World Bank 2015*c*).

Prioritisation of infrastructure investments for the state during colonial times, and post-independence — when it was the Nigerian capital<sup>4</sup> — facilitated its current position as the centre of commercial activity in the country (Abiodun 1997, Leke et al. 2014). This

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<sup>4</sup>Lagos was replaced as Nigeria's capital in 1991 by the Federal Capital Territory of Abuja (Morah 1993).

concentration of economic activity and (perceived) opportunity in one state, encouraged migratory pressures that the state has been ill-equipped to deal with. In 1952, the population of Lagos was 250,000; in 2010 the state was home to over 10 million people (Ajibade & McBean 2014).<sup>5</sup> Lagos is now home to people of various ethnic groups that have migrated not just from surrounding states in Nigeria, but from the West Africa sub-region, who place great hope in the promise of the state (Obono 2007, LBS 2013). This rapid growth into a megacity was not accompanied by — and did not stem from — prosperity and development; and thus the state has been absent the income and facilities needed to meet the needs of its growing population (Obono 2007). This high level of urbanization, combined with a lack of adequate planning, and national economic and political instability, quickly led to a city-state with inefficient connectivity, poor social services, poverty, and inequality (UN-Habitat 2014).

Today, Lagos is a state with multiple faces. The densely populated centre of the state is the metropolitan hub of commercial activity, made up of impoverished slums sitting alongside wealthy communes. Further out, nearer the borders of the state are highly dispersed primitive rural communities. The state is a symbol of the inequality found at the national level between the few rich and many poor, which drives its unsustainable in-migration. This blend of social conditions in the state amidst wider societal dysfunction leads to a peculiar environment for politics, institutions, and markets. An environment all residents of the state, no matter their social-cultural identity, interact with to sustain their livelihood.

## **6.3 Lagos and Nigeria: External political, institutional and market environment**

This section will describe various markets that consumers interact with directly and indirectly, and any government policies at the national and state level that have influenced resulting situations. As presented by Van Der Kroon et al. (2013), some of the markets worthy of note — due to their influence on the decision-making process of households regarding energy — include; security systems, the labour market, capital markets, technology markets, and markets for other consumer goods.

### **6.3.1 Livelihood security (security markets)**

Security markets here refer to the systems that secure the livelihood of a consumer, whether household or business, with implications on energy service provision and consumption. These include the security of persons, personal or public property, rights, and the services and provisions that ensure the security of livelihood and well-being on a daily basis — including

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<sup>5</sup>Figures on Lagos state's population have been subject to variation. This research uses the UN adopted figures (see Chapter 8).

the provision of energy services. This section will touch on how the security systems in place for businesses, energy infrastructure, land rights, housing, and an individual's well-being shape up in Lagos and Nigeria, and the sorts of behavioural tendencies that exist as a result.

### ***Business, private property, and infrastructure security***

Nigeria ranks number 169 out of 183 economies on the ease of doing business, according to the World Bank (World Bank 2014b); a ranking that has dropped steadily since it ranked 120<sup>th</sup> in 2008. This reveals some of the practical difficulties posed when setting up and running a business in the country; and Lagos is no exception, with many of its indicators worse off than the average for Sub-Saharan Africa (see World Bank 2014b).

Particularly problematic in the country, which the doing business methodology does not cover, is the security of public and private property from theft and vandalism; notably on complex and large-scale infrastructure. The oil & gas and power industries have been subject to such crimes, to the detriment of the national energy sector as a whole. Ineffective and opaque management of petroleum resources, corruption, poverty, and environmental pollution leading to loss of local livelihoods, has given rise to disenfranchised groups in the oil-producing Niger Delta region in the south of the country (Yeeles & Akporiaye 2016). The result has been a pervasive practice of oil bunkering and pipeline vandalism that have hindered the productivity and growth of the sector; and crucially the stability of fuel supply for power generation (APT 2015). Oil theft in 2013 was estimated at 150,000 barrel per day (6% of daily total), in addition to resulting spills representing losses in revenue to the tune of over \$5 billion per year (IEA 2014a).

The country's power sector has also been subject to electrical equipment vandalism, and high levels of non-technical losses (Oseni 2011). Trust issues among the people, and with their governing bodies, in addition to difficulties enforcing the rule of law fuels much illegal activity in the country;<sup>6</sup> such that communities in Lagos police themselves with neighbourhood vigilante groups, and many households and organisations make use of private security personnel which serve to further undermine law enforcement (Obono 2007).

### ***Land security***

Another area of insecurity that adversely affects the provision and consumption of energy services in Nigeria is the country's land tenure system and management of its forest resources. For decades there has been a legislative vacuum for the nation's forests; resulting in overlapping roles between states and the federal government that have hampered sustainable use of forest resources (USAID 2010). The Land Use Act 1978 nationalised all land in

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<sup>6</sup>Examples of malpractice provoking mistrust include: unfulfilled promises of power infrastructure from government officials for political expedience (Adedayo 2014); and poor metering leading to estimated billing practices, amidst electricity supply instability (Oseni 2015).

the country as a means to ensure equitable access to land for all Nigerians, curb speculation, and encourage productive use of land (FGN 1978). But problems with its design have made it difficult to achieve the above aims in practice, and also introduced insecurity (Olayiwola & Adeleye 2006).

The Land Use Act gives power to state and local authorities to provide occupancy rights in urban and rural areas respectively (FGN 1978). A lack of citizen awareness, however, typically renders most land transactions taking place in informal markets; increasing the insecurity of rights (USAID 2010). Institutions without the necessary funding to carry out the duties afforded them by the legislation, particularly at the local level, means that the preceding customary land tenure system governed by local traditional rulers forms the basis of land distribution in the country (Blench et al. 2006, USAID 2010). This maintains inequitable processes against women and migrants, and tenure systems that differ depending on the community (Aluko & Amidu 2006, Braimoh & Onishi 2007). Disputes are also common place amidst ad hoc partitioning of land and inheritance customs that have been observed to hinder productivity and investment (Yusuph & Nwabuisi 1999, USAID 2010).

In line with other difficulties of undertaking business in Nigeria, the formal process of obtaining rights to land has been observed as arduous, time-consuming, and costly, further encouraging informal transactions (World Bank 2014*b*). As is found with laws that govern many other sectors of the Nigerian economy, there is a lack of detailed standardised processes in the administration of land occupancy rights, leading to discretionary powers for state governments that lead to corrupt practices to the detriment of the poor.<sup>7</sup> For example, state governments can determine for themselves what lands are considered urban or rural, and can freely expropriate lands absent timely and appropriate compensation (FGN 1978, USAID 2010). The above issues make it difficult not only for the establishment of infrastructure — such as energy systems — but hamper the ability for the poor to equitably increase the productivity of their land resources, and encourages unsustainable harvesting of biomass resources.

### ***Housing security***

This precarious system of land tenure in the country feeds insecurities in its housing sector; particularly in Lagos state. Population growth concentrated in the central Lagos metropolis, combined with a land acquisition process that favours the wealthy, places significant pressure on the state's housing stock (Braimoh & Onishi 2007, Ibem 2011, Makinde 2014). Dilapidated structures at high risk of collapse are overcrowded, with tenants paying relatively high rents (Atilade 2018). Large populations are forced to live in informal structures with poor sanitation, as refuse dumps and the coast of the Lagos Lagoon have been converted into ad

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<sup>7</sup>See Gillies (2009), Sayne et al. (2015), and GIZ (2014), for discussions on malpractice in Nigeria's petroleum sector, linked to similar gaps in administrative clarity.

hoc communities at constant risk of demolition by state authorities (Nwanna 2012, Ajibade & McBean 2014). It is estimated that two in three Lagos' residents live in slum conditions (Ajibade & McBean 2014).

The contradiction of these communities is that just as their informal nature inhibits the provision of critical services, so does it also facilitate local behaviours that are detrimental to their surrounding environment, infrastructure, and services. Power instability in the state is exacerbated by unauthorized connections (Oyedepo et al. 2014). The state has endured numerous instances of flooding at the height of its rainy season, as its flood resilience is eroded with blocked drainage systems; with slum dwellers, forced to reside in flood-prone areas worst affected, suffering displacement and fatalities (Ajibade & McBean 2014).

### ***Social security***

Social protection in Nigeria suffers from all similar ills that plague the sectors discussed above. Owing to the lack of dedicated national policy on social security, there is a multiplicity of uncoordinated actors at the state, local and federal level; with ad hoc interventions that can only achieve a limited level of coverage (Holmes et al. 2012). In contrast to welfare spending found in some western countries, social protection in 2010 accounted for a meagre 1.4 % of federal government expenditure (Hagen-Zanker & Tavakoli 2012). There are examples of implemented programmes succumbing to the same corrupt practices that plague the country; such as a mismanagement of funds by community members in a community-based health insurance programme in Lagos (see Holmes et al. 2012). Such an experience serves as warning that absent careful implementation and consideration of the social context in which projects are being implemented, access strategies that involve community leadership which proved successful in other countries (see Section 4.3), can fail. Many locals are therefore vulnerable to shocks in their income, health and food, and are subject to discrimination and inequality within and outside their homes; which will impact the decisions they take in order to secure their livelihoods (Eboh & Oluwadare 2007, Holmes et al. 2012, Umukoro 2013).

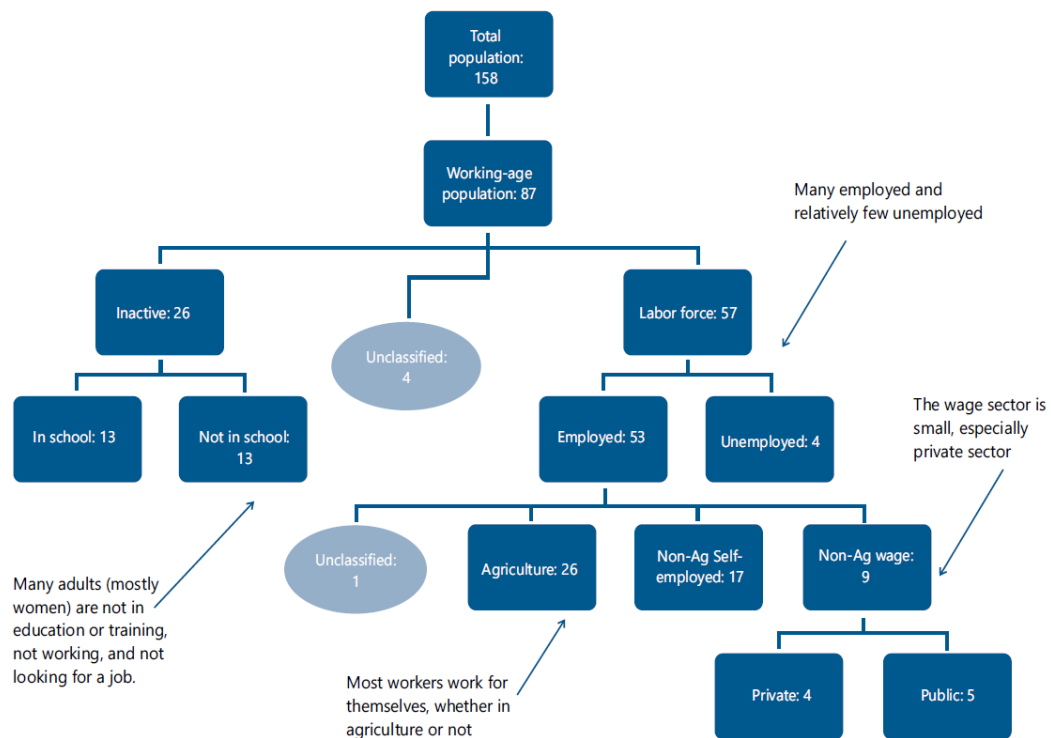
### **6.3.2 Labour market (income opportunity)**

#### ***Labour market structure***

Labour is another important driver of the decisions households make on a daily basis, including their demand for services; because it influences local culture, consumer affordability, and the services available to them. The UN estimate that 53.8 % of Nigerians are income-poor; that is, live below PPP \$1.90 per day (UNDP 2016). Although employment is high among the active labour force (93 %), the high poverty situation is indicative of the nation's labour market; which is characterised by low-paying and low-productivity jobs, and high informality (World Bank 2015b). Over 80 % of the labour force engage in self-employed work, either through smallholder farming or non-farm household enterprises. The latter

largely consists of low-paid and low-productivity services, such as small-scale retail trade, personal services, and food preparation (World Bank 2015*b*). It is estimated that 75 % of those working in employed labour operate informally (World Bank 2015*b*); while a large portion of formal employees work in the public sector (see Figure 6.3), where payment of salaries has been notoriously inconsistent (World Bank 2016*a*).

**Figure 6.3:** Structure of Nigeria’s labour market (millions)



Source: World Bank (2015*b*)

Note: Nigeria’s total population figure depicted in this graph was estimated by the World Bank (2015*b*) for the year 2011, based on nationally representative surveys conducted by the country’s National Bureau of Statistics (NBS).

### ***Large informal economy***

Similar to other SSA countries, over 90 % of Nigeria’s labour force operates in the informal economy — that is, employed in the informal sector as well as informal employment in the formal sector — which contributes to a lack of access to social security for workers (Charmes 2012, Favara et al. 2015). This high informality adversely impacts the government’s ability to effectively regulate the market, and also affects government revenue through lower tax receipts, making it difficult to adopt a public-sector budget that reflects the growth requirements of the country (PCL 2014). Because productivity of work is low, wages relative to the cost of living are depressed, and workers seek multiple jobs to make ends meet; and in many cases require children to couple school with work to support household incomes

(World Bank 2015b).

### ***Results of Lagos in-migration***

By virtue of being the commercial centre of Nigeria, many of the wage jobs can be found in Lagos where there is a greater demand for employees in the services and industry sectors (Yusuf 2014). Nevertheless, the same opportunities that attract workers in the formal sector to the state also attract unskilled workers. Retail trade in Lagos is largely informal and fragmented; with in-migration bringing an abundance of traders to operate with limited market infrastructure. Informal road-side trading is a common feature and as an extension, street-trading — where sellers attempt to make sales to consumers in traffic (Lawal 2004). The security of work for these labourers is often under the threat of government displacement, as their activities disrupt transportation, the development of road and sewage works, and exacerbate waste management amongst others (Ikioda 2016). There is also a gender dimension to this insecurity of work, as women are the dominant labourers in road-side trading in Lagos, and in the informal economy in general (Charmes 2012, Ikioda 2016).

### ***Inadequate skills development***

Nigeria's labour market also suffers from an inadequate supply of skilled personnel. Illiteracy in the country doesn't only stem from those that do not attend school, but from substandard quality of formal education in many areas of the country (Favara et al. 2015). Once again the institutional framework that governs the education system across the federal and state levels is wrought with complexities, and unclear roles and responsibilities that diminish accountability, which in turn hampers funding for necessary teaching resources, leading to poor learning outcomes (Odia & Omofonmwan 2007, Favara et al. 2015). The energy market, like other consumer markets, is contingent on the skills required for operations, research, and innovations that respond to the local context and beyond, and also the productivity of labour that will provide consumers with the earnings required to afford services on offer. The largely informal and agro-based economic structure of Nigeria, where workers take on multiple jobs influenced by seasons, drives societal behaviours which ultimately affect access to energy services and resulting household decision-making.

#### **6.3.3 Capital market (financing capacity)**

As discussed in Chapter 3, access to finance is a key enabler, and currently, stumbling block, for transitions to modern energy services. Nigeria presents a peculiar macroeconomic situation that renders access to finance for businesses and individuals particularly challenging.

Since the height of the 2008/09 global financial crisis, inflation in the country has been no lower than 8% year on year; reaching over 18% in 2016 following a depreciation of the country's currency after world oil prices fell considerably (CBN 2018). At 8% inflation, borrowing costs are as high as 20%, representing why businesses in Nigeria consider *access*



to finance to be their biggest barrier (Leke et al. 2014, World Bank/IFC 2015). Less than a third of micro, small and medium enterprises are said to have obtained financing from formal financial institutions, including MFIs (EFInA 2014, World Bank/IFC 2015, CBN/IFC 2017).

Smaller firms — the sort that have been instrumental in expanding the distribution of off-grid energy services in other contexts — who lack collateral required to obtain a bank loan or line of credit suffer most, and are forced to rely on personal finances and informal sources of finance (e.g. friends and family) (CBN/IFC 2017). The extension of concessional finance from the government at the federal level and from the Lagos state government has tended to be sporadic with issues in the administration of funds (LASMI manager 2013, personal communication, 14 May; SELCO Foundation 2016). Other funding extensions for particular activities or technologies, such as agriculture or modern energy technologies, have also involved development institutions, but issued on a small scale (GIZ 2014). The situation is in contrast with experiences such as those seen in China and other countries with successful roll-outs of modern energy, where concessional finance for dedicated development projects were nation-wide and sustained (see national examples in Chapters 3 and 4).

At the consumer level, only 44 % of Nigerian adults had a transaction account in 2014 according to data from the World Bank’s Global Findex database (World Bank 2018b).<sup>8</sup> In rural areas, percentage access drops to circa 39 % for the same year (EFInA 2014, World Bank 2018b). According to 2017 estimates, the percentage access for both indicators have fallen (39 % for the national estimate, and 33 % for the rural areas) (World Bank 2018b).

Mobile money has been a key enabler of innovation and accelerating consumer access to modern energy services around the world (see Section 3.4), but Nigeria has been slow to grow this industry despite fair development in its telecommunications reach. Mobile phone subscriptions have grown from 30,000 subscribers in 2000 to 154 million in 2016 (World Bank 2018d). However in 2014, it was estimated that only 12 % of the country’s adult population were aware of mobile money (EFInA 2014), and under 3 % of them made use of it (World Bank 2018b).<sup>9</sup> This limited penetration of mobile money usage in Nigeria has been attributed to regulatory issues that limit the role of mobile network operators (MNOs) in the provision of financial services (Smertnik 2016); a role that has been deemed critical to the growth of the mobile money industry in other contexts (GSMA Intelligence 2014). Similar

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<sup>8</sup>The Global Financial Inclusion (Global Findex) database provides “detailed insight into how adults in more than 140 economies access accounts, make payments, save, borrow, and manage risk” (Demirgüç-Kunt et al. 2018, p. xi). Launched in 2011, it is “the world’s most comprehensive data set on...access to and use of formal and informal financial services” (ibid., p. xv).

<sup>9</sup>In 2014 Nova Lumos — a PAYG solar system provider — partnered with the mobile network operator MTN to pilot PAYG provision of solar home systems in Nigeria using airtime credit, which is more readily used in the country as opposed to mobile money. Encouraging results from the pilot led to US\$15 million debt investment from U.S. development institution OPIC (Roach & Cohen 2016). Although the technical integration between PAYG system provider and mobile network operator is more complex for the airtime PAYG business model than it is for mobile money (ibid.), it indicates how familiar practices within the country can be leveraged to influence consumer decision-making, and in this case, energy access.

to SME dependence on informal sources of finance, remittances are an important form of support finance to households in Nigeria’s cultural setting (NBS 2016). Since support from family and friends can be sporadic, some consumers might find greater comfort making cash transactions as opposed to transactions based on promises of future payment.

### 6.3.4 Technology/input goods (energy service capacity)

The technologies and inputs used in production and the provision of consumer services are a major driver of behaviour and decision-making in any society. In a direct manner they affect decision-making and processes across all productive sectors (e.g. agriculture, midstream petroleum, power generation, telecommunications, etc.) as well as the decisions of consumers when undertaking various activities (bathing, eating, cleaning, etc.). In this section, focus will be given to energy sector (conversion) technologies and inputs (energy carriers) that have direct interaction with households, to review the socio-technical landscape for household energy services in Lagos and Nigeria at large. A distinction is made between reticulated energy provision (such as networked utility provision of electricity or gas) and non-reticulated energy (i.e. self-service private generation), not only because of its relevance in this context, but due to the difference in socio-technical interaction; where the latter requires the consumer adds *producer of final energy* to its roles and responsibilities.

Owing to some sector-specific governance issues, and influenced by — but also influencing — the state of markets reviewed in earlier sections, Nigeria’s energy sector operates well below its desired level of efficiency (Munro et al. 2017). The country is classed as one of the high impact countries by the SE4All’s global tracking framework for achieving universal access to modern energy services. It ranks second, behind India, among the countries with the highest number of people without access to electricity, and is ranked third globally on the number of people without primary reliance on non-solid fuels for cooking and heating; only behind China and India (World Bank 2017a). The country’s energy indicators are amongst the worst levels regionally and globally; these are reviewed in discussions under the subheadings that follow.

#### ***Reticulated electricity poverty***

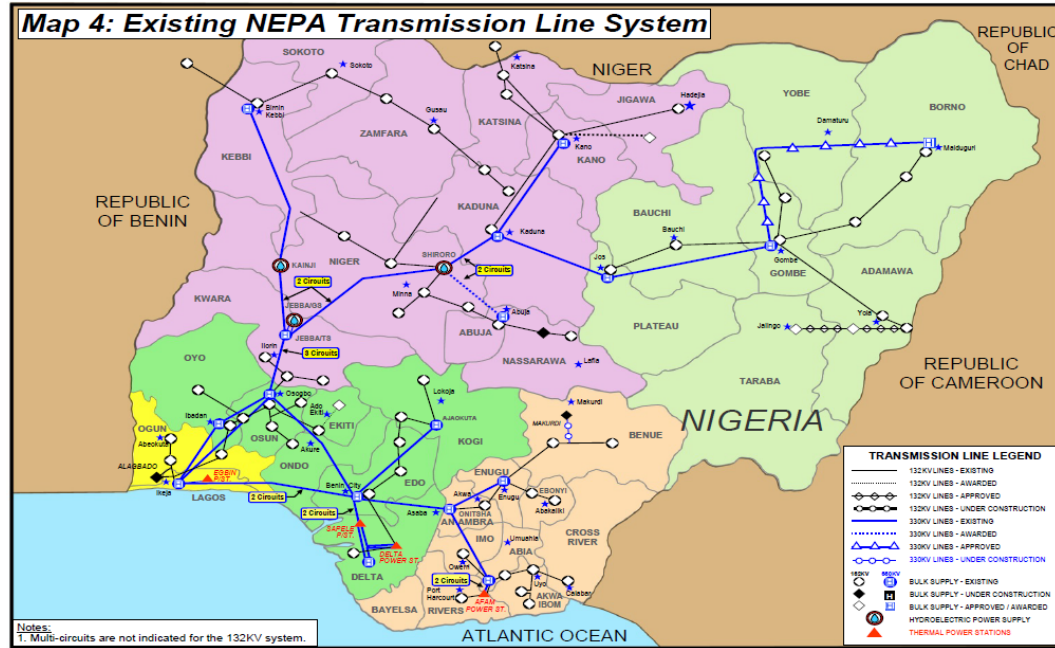
As at 2016, Nigeria’s reticulated (grid or mini-grid) electricity access stood at 59 %, with the percentage of its population with access to clean fuels and technologies for cooking at 5 % (NBS 2016, World Bank 2018c).<sup>10</sup> Access levels for 2013 were 56 % and 3.5% respectively (World Bank 2018c). Connection to the electricity grid averages 86 % in urban areas contrasting with 41 % in rural areas of the country (NBS 2016, World Bank 2018c). This

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<sup>10</sup>According to the in-text cited sources, the electricity access data is based on Nigeria’s General Household Survey measure of reticulated (national grid or rural electrification mini-grid systems) electricity access. The clean fuels data does not include kerosene users (i.e. different from the *non-solid fuel* measure of cooking access, which was closer to 24 % in 2012).

disparity between urban and rural areas also represents differences between access levels across geopolitical zones of the country; where access levels in the Southwest region average 75.3 %, and are as low as 25.9 % in the Northeast region of the country (NBS 2016). Figure 6.4 provides an illustration of the country's electric grid network in 2011.

**Figure 6.4:** Nigeria's electric grid distribution network



Source: Nnaji (2011)

Lagos has the highest level of electricity connectivity of all states in Nigeria at circa 90 % (GIZ 2014, Atkins/LSEB 2014). However most of these connected areas remain in energy poverty due to difficulties with poor availability of supply. In 2013, average per capita electricity consumption in Nigeria stood at 142 kWh, ranking the ninth lowest level globally; lower than the SSA average of 488 kWh, and indeed lower than the average of UN-classified least developed countries of 191 kWh (IEA 2014a). Figures on generating and wheeling (electric power transmission) capacities of 3879 MW and 3592 MW respectively, fall well short of an estimated demand of 10 100 MW (Brew-Hammond et al. 2014, APT 2015). Records show capacity losses during electricity generation, transmission, and distribution leading to approximately 25% of the installed nationwide capacity being delivered to consumers on an average day (see APT 2015). This has necessitated the long-standing practice of pre-calculated percentage load allocations to the distribution companies operating in different zones of the country; in addition to load shedding by distributors. Although Nigeria's population share with electricity access is higher than the SSA average, those with access experience the second highest number of annual outage-hours worldwide (IEA 2014a).

## ***Personal utilities***

Frequent blackouts and brownouts characterise supply right across the country; with average weekly supply in 2013 estimated at 35 hours per week (NBS 2014), and blackouts lasting in excess of 12 hours for most households, particularly in rural areas (MTI 2013). Between 2013 and 2015, circa 40 % of households reported receiving electricity for between 1 to 4 hours before a blackout occurred (NOIPolls 2015). Given the precarious state of utility supply, many consumers (households, industry, and business) are forced to diversify their supply of utility services. This extends beyond energy services, and also includes utilities such as water supply. In the case of electricity, self-generation is primarily done using diesel and gasoline generators, but also with the use of batteries and home solar in some areas of the country (NBS 2014, Upadhyay et al. 2013).

For households that have access to, and can afford the operation of private diesel or gasoline generators, these have been the preferred choice of backup electricity. Despite the high cost per kWh of self-generated electricity (more than twice the cost of grid electricity in Nigeria (IEA 2014a, APT 2015)) the elite and middle class are highly dependent on private generation. Low income earners sometimes own or pool their resources to engage with portable sized gasoline generators for low loads such as lighting and mobile phone charging (Upadhyay et al. 2013). The incidence of use is particularly high in port-cities such as Lagos, acting as a hub to fuel one of the largest generator import markets worldwide (estimated at \$250 million in 2011 (World Bank 2014a)). National survey data recorded 32 % of households in the Southwest region of the country relying on a private generator, either exclusively or as backup to the electricity grid (NBS 2014). Other private independent surveys however, cite the nationwide use of generators to be as high as 81 % of Nigerian households (NOIPolls 2015). This disparity may stem from differences in survey techniques, but may also result from the highly nuanced realities surrounding use and ownership.

The makeup of household energy services in Nigeria goes beyond networked and off-grid electricity. The generation of private electricity for the average low-income home is predominantly used to meet household lighting and other low load electricity-based services, such as space cooling (using a fan), televisions, mobile phone charging, and radio; and higher-income households would own and power higher-load appliances such as air-conditioning using private diesel generators (NBS 2012, Upadhyay et al. 2013, NBS 2014, 2016). But some households lack access to any form of electricity supply, or make limited use of electricity. In addition, Nigeria does not have the infrastructure for networked energy supply on a broad scale for another important energy service, cooking; such as reticulated gas supply. Therefore, non-electric energy plays an important role in the household energy consumption for a range of services; including those met by electricity, such as lighting. These sources include fuelwood, kerosene, LPG, charcoal, animal waste, crop residue, non-rechargeable

batteries and candles (NBS 2014, 2016).

Although fuel stacking is common practice amongst household consumers, unsustainably harvested biomass and kerosene are the two most widely used cooking fuels in Nigeria with approximately 45.5 % and 46 % of households adopting them respectively (NBS 2014). The country's per capita daily consumption of traditional biomass is among the highest in SSA.<sup>11</sup> In a state like Lagos, which has a notable urban presence, kerosene is used extensively for both cooking and lighting services; while in rural areas of the state and the country, households engage in greater use of freely accessible fuelwood (NBS 2014, 2016). The use of charcoal is reserved for specific cooking purposes, and LPG is a fuel largely adopted by higher-income households.

### ***Nigeria's conventional energy market***

The state of energy access in Nigeria has emerged from historical experiences that influence the management of the country's resources and the social contract between the government and the public. Limited public trust in the government, low government administrative capacity, and the informality of the country's economy have all restricted the ability for Nigeria to run a fiscal policy that is based on domestic taxation and revenue mobilisation from its extractives industry. The IMF ranked Nigeria 52<sup>nd</sup> in its index of public investment efficiency of a group of 71 low and middle income countries (Dabla-Norris et al. 2011). Paradoxically, instead of petroleum revenues being invested domestically towards the provision of infrastructure, education and healthcare, inefficient energy subsidy programmes have been run for decades to fulfil the social contract between the government and the public (IISD 2012). As a result of the government's intervention, the energy market has struggled to develop, with price instability and instances of fuel scarcity, and a consumer base that do not know the true value of the energy services they consume.

In 2013, 95 % of crude oil production and 61 % of natural gas production was exported (highlighted in Table 6.1), despite 85 % of the country's installed power generation capacity being based on thermal plants (APT 2015). Domestic refining operates as low as 20 % of its total 0.45 mb/d capacity (IEA 2014a).<sup>12</sup> The bulk of oil products (diesel, gasoline, and kerosene) acutely relied on for private consumption are imported (highlighted in Table 6.1) and have been heavily subsidised; with costs as high as \$13 billion in 2011 (IISD 2012); placing a heavy burden on federal budgets (circa over 30 % of the federal budget in 2011) (World Bank 2012a, Mills 2017).<sup>13</sup> In 2010 Nigeria had the lowest pump price of gasoline in

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<sup>11</sup>An estimated 130,000 premature deaths in Nigeria are as a result of household air pollution from traditional biomass cooking, and indoor kerosene use (IEA 2016).

<sup>12</sup>Total installed domestic capacity would be sufficient to meet an estimated domestic demand of 0.4 mb/d of oil products (IEA 2014a).

<sup>13</sup>At the time of this research's fieldwork and analysis, the diesel subsidy was no longer in place, but the subsidies for kerosene and gasoline remained; until 2016 when the Buhari administration discontinued subsidies for the latter two.

**Table 6.1:** Nigeria energy balance 2013 (*thousand tonnes of oil equivalent*)

Source	Coal*	Crude Oil*	Oil Products	Natural Gas	Nuclear	Hydro	Biofuels and waste	Electricity	Heat	Total**
Production	27	115956	0	30350	0	458	108868	0	0	255660
Imports	0	0	8752	0	0	0	0	0	0	8752
Exports	0	-110723	-1101	-18554	0	0	0	0	0	-130378
International Marine Bunkers***	0	0	-365	0	0	0	0	0	0	-365
International Aviation Bunkers***	0	0	-361	0	0	0	0	0	0	-361
Stock Changes	0	-39	321	0	0	0	0	0	0	282
<b>Total Primary Energy Supply</b>	<b>27</b>	<b>5195</b>	<b>7246</b>	<b>11797</b>	<b>0</b>	<b>458</b>	<b>108868</b>	<b>0</b>	<b>0</b>	<b>133591</b>
Transfers	0	584	-522	0	0	0	0	0	0	63
Statistical Differences	0	0	1	424	0	0	0	0	0	426
Electricity Plants	0	0	0	-5079	0	-458	0	2491	0	-3047
Oil Refineries	0	-5445	5151	0	0	0	0	0	0	-295
Losses	0	-334	-61	0	0	0	0	-382	0	-777
Other Transformation	0	0	0	0	0	0	-8258	0	0	-8258
Energy Industry Own Use	0	0	-480	-4006	0	0	0	-89	0	-4574
<b>Total Final Consumption (TFC)</b>	<b>27</b>	<b>0</b>	<b>11335</b>	<b>3137</b>	<b>0</b>	<b>0</b>	<b>100610</b>	<b>2020</b>	<b>0</b>	<b>117128</b>
Industry	27	0	405	2036	0	0	6997	335	0	9801
Transport	0	0	8227	0	0	0	0	0	0	8227
Residential	0	0	529	0	0	0	91227	1157	0	92914
Commercial and Public Services	0	0	1	0	0	0	2385	527	0	2914
Agriculture/ Forestry	0	0	4	0	0	0	0	0	0	4
Non-Specified	0	0	2141	0	0	0	0	0	0	2141
Non-Energy Use	0	0	28	1100	0	0	0	0	0	1128

Source: Adapted from IEA (2013)

Note: \* The column of coal also includes peat and oil shale where relevant; that of crude oil, NGL, refinery feedstocks, additives and other hydrocarbons.

\*\* Totals may not add up due to rounding.

\*\*\* International marine and aviation bunkers are included in transport for world totals.

SSA with \$0.44/l; compared with international EU benchmark prices for the same year of \$1.46/l, with global crude oil price at \$0.54/l (World Bank 2012*a*). 2012 prices show subsidies for gasoline and kerosene accounting for 43 % and 68 % of the total price of importation and distribution respectively (IISD 2012). Similarly, electricity subsidies in Nigeria are such that despite 2013 average generation costs in the West Africa region of \$140/MWh, households on average were charged below \$100/MWh (IEA 2014*a*); while domestic gas prices have come nowhere close to competing with international prices (IEA 2014*a*).

Government insistence on maintaining low electricity prices that do not reflect market costs, despite legislation to the contrary, have hampered reform results — that included privatisation — affecting sector performance improvements (APT 2015, Kukoyi 2015, Eberhard et al. 2016).<sup>14</sup> As is typical of many subsidy policies, Nigeria’s fuel subsidies are not targeted effectively and higher income households are the main beneficiaries (IISD 2012, Mills 2017); poor households in rural areas are sometimes faced with black market kerosene prices of more than three times the official subsidised price due to a disorderly supply chain (IISD 2012).

### ***Nigeria’s clean energy market***

The Government’s involvement in Nigeria’s energy sector makes it a difficult environment for introducing and establishing a market for new energy services and technologies; as businesses cannot predict government behaviour and consumers are presented with uncompetitive markets. Nigeria has an abundance of renewable resources in the form of hydro, solar, wind, tidal, and biomass (see Table 6.2). With the exception of hydro and biomass — through large hydropower generation and unsustainably harvested household biomass — the above renewables are vastly underutilized, and the market for their decentralized application, including small-scale off-grid systems, is not well developed (GIZ 2014); despite their relevance for un-electrified households (Mentis et al. 2015).

In addition to the subsidies on petroleum products there are a number of country-specific situations that have held back the market for renewables, both utility scale and off-grid. Firstly, despite a number of white papers outlining plans to develop renewable energy utilisation in Nigeria, there is no dedicated legal and regulatory framework enshrined in law

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<sup>14</sup>The underlying post-privatisation issue with the Nigerian electricity market is a vicious cycle that perpetuates a pre-existing cash-flow problem. The tariff is not cost-reflective and the Aggregate, Technical, Commercial and Collection (ATC & C) losses are too high. This, together with vandalism of power and gas infrastructure brings about fluctuations in generation and maintains grid instability. The resulting erratic supply of power diminishes consumer confidence and produces an unwillingness to pay higher energy bills. Right along the value chain, there is then a lack of confidence from all stakeholders in the system that they will receive or be paid their just due (Ogunleye 2016).

**Table 6.2:** Nigeria’s renewable resources

Resource	Potential	Current utilisation
Large hydropower	<10 000 MW	1900 MW
Small and medium hydropower	<3500 MW	64.2 MW
Solar	3.5–7 kW h/m <sup>2</sup> /d	6 MWh/d
Wind	2–4 m/s at 10 m height (mainland)	–
<i>Biomass resources</i>		
Fuelwood	>11 million ha	43.4 million tons/yr
Animal waste	61 million tons/yr produced	–
Energy crops	28.2 million ha of arable land	8.5% cultivated
Agricultural residue	91.4 million tons/yr produced	–
Municipal waste	circa 0.5 kg/capita/d	–

Source: Adapted from GIZ (2014) and Usman et al. (2015)

to direct their implementation.<sup>15</sup> Secondly, some of the characteristics that have allowed off-grid generation to gain traction, with limited regulatory provisions, in East Africa do not exist with Nigeria.<sup>16</sup> Countries such as Kenya and Tanzania have the bulk of their population off the grid (2012 grid access levels were 30.3% and 15.3% respectively (World Bank 2018e)), some are landlocked, and not endowed with petroleum resources; all of which make conventional fuel supply expensive, as compared for example to the freely available solar resource (IEA 2014a).

Third, Nigeria’s history with off-grid energy services and energy access activities — that involved failed technologies, rural electrification agency malpractice, and sporadic donor-sponsored pilot projects (Ohiare 2014, GIZ 2014) — has affected consumer confidence in renewable technologies. Furthermore, such is the attraction for imported consumer products in Lagos and Nigeria at large, that renewable energy technologies of wide-ranging quality make up the domestic market, exacerbating technology trust issues. Growth in public awareness of renewable technology and its access mechanisms has been slow in Nigeria, resulting in a problem of information asymmetry between consumers and suppliers, amidst limited quality control mechanisms (Upadhyay et al. 2013). As one industry participant laments:

“lack of proper regulations and policy, it brings about a lot of infiltration into the market. So even if you had a solid solution that you know is dependable,

<sup>15</sup>Plans to develop renewable energy utilisation in Nigeria are guided by a number of white papers. Beginning broadly with the National Energy Policy 2003 and the National Economic Empowerment and Development Strategy 2004 (NEEDS) (Emodi & Ebele 2016). More specific plans for renewable energy development are found in the Renewable Energy Master Plan 2005 (REMP), which laid the foundation for a national vision and targets that shaped the development of the Renewable Electricity Policy Guidelines 2006 (Ogunl-eye 2016, Emodi & Ebele 2016). Specific plans for the development of biofuels were laid out in the 2007 National Biofuels Policy (Abila 2012, Giwa et al. 2017). And most recently the National Renewable Energy and Energy Efficiency Policy 2014 (NREEEP) and the Rural Electrification Strategy and Implementation Plan 2014 (RESIP) give greater attention to the off-grid sector (REA 2014, FGN 2015).

<sup>16</sup>Kenya for example, has seen its pico-solar market grow exponentially from 57,000 quality-verified products sold in 2010, to just under a million quality-verified products sold in 2014 (Orlandi, Tyabji, Chase, Wilshire & Vickers 2016).



the fact that you have to combat with fake inferior solutions...creates a kind of bottleneck, and then makes it a bit unbearable. Same solution that you know, that is delivering something quality that will cost about 5 million naira, and somebody is promising them that they will do it at 2 million naira, you know that in 6 months, it's going to be a failed project. So the mentality is that this one is cheaper" (country general manager–multinational energy technology and solutions corporation 2013, personal communication, 11 November)

In 2013 the federal government moved to encourage the use of solar energy by exempting imported solar panels from duty payments; but this does not extend to fully integrated solar systems — such as solar lanterns, where the panel, battery, and lamp all form part of a single device (Upadhyay et al. 2013). Integrated devices face import duties between 20 and 35 % (ODI 2016). Thus, renewable lighting devices have limited cost-competitiveness in the Nigerian market, given the other lighting devices available. While 2013 solar lantern costs range from \$10–\$63, rechargeable lanterns/torches can range between \$7.5 and \$32, and as low as \$0.95 for non-rechargeable lanterns (Upadhyay et al. 2013).

As mentioned earlier, Lagos is a hub for imported products that are demanded and distributed across all states in Nigeria, and also to neighbouring countries in the east, north and west. But because of the relatively higher costs of solar lighting devices and limited awareness, natural market forces do not encourage their supply beyond major markets, to low-income rural areas. Dedicated projects and practitioners seeking to promote stand-alone renewable technologies in rural areas have been driving this market; requiring much effort to encourage necessary support services in these areas, absent the economic linkages needed to grow and sustain markets.

### **6.3.5 Consumer goods (non-energy livelihood necessities)**

The focus here is on non-durable consumer goods. Goods such as food, services, and some other fast-moving consumer goods (FMCG) that are important components of consumer expenditure, particularly for the poor; access to which are influenced by energy (to support provision) and in competition with energy (for household resources). The average Nigerian allocates a portion of their monthly expenditure to food, soap and other washing materials, mobile recharge cards, transportation, and the most common household fuel — kerosene (NBS 2014, 2016). However, as detailed in some of the earlier sections, low productivity, and thus a relatively heavy reliance on imports for non-durable goods such as food (FAO 2017), an unfavourable exchange rate that impacts local purchasing power of imported goods, and poor infrastructure such as transportation infrastructure, leading to high transportation costs — all contribute to a high cost of living in Nigeria. According to some estimates, prices in Nigeria are 40 % higher than those in Indonesia and 90 % higher than those in India, with

Nigerians needing to earn more than twice as much as Indian households in order to meet basic needs in the form of food, energy, education, housing, sanitation, water, etc. (Leke et al. 2014).

Inefficient transportation is a particular driver of high prices, with a major impact on the cost of food; estimated to take up as high as 74% of the poor's expenditure (Leke et al. 2014). In Lagos for example, both urban and rural locales suffer from inefficient transportation; as unmaintained roads and poor road connectivity cripples the state urban area with traffic congestion, while its rural areas have limited connectivity to metropolitan Lagos. Combining this with volatile transportation costs, shocks to food access for poor households are common; which households must respond to with modifications in their consumption (both food and non-food) while attempting to sustain their livelihoods (NBS 2014, 2016). Attempts to cope with access shocks to important basic needs can impact other expenditures and — amidst limited social safety nets and access to credit — can have important consequences on short-term demand. High transportation costs have also been known to affect services such as healthcare access, as consumers are unable to afford clinical visits, and also deter parents from sending children to school (Holmes et al. 2012).

Another basic necessity that households have difficulty accessing, bringing further pressure on their freedom of choice and on their expenditures, is water. For example, the state of poor water supply in Lagos and most areas of Nigeria, means many low-income consumers are forced to purchase their daily water requirements from street vendors at very high prices; placing a squeeze on the reach of their income with other consumer goods (Macheve et al. 2015). In some cases, such as in rural areas, poor access to water necessitates water collection and bathing in nearby rivers.

The above sections have presented the condition of some key markets at the state and national levels that describe the external environment in which households make decisions. The section that follows seeks to present a closer picture on the attitudes, experiences and capabilities of households in the rural region of Lagos chosen for fieldwork, to shed light on the micro forces and characteristics that drive and describe life in Epe.

## **6.4 Life as a resident of the Epe LGA**

As introduced in Chapter 5, this research selected five communities in which to conduct primary research; Igbodu, Elujo-Imowo, Itokin, Oriba, Ketu. All these communities fall under the local governance of the Epe local government area (LGA) — which is one of 20 local governments in Lagos state — but the communities differ according to their economic and socio-cultural makeup. In this section, detailed descriptions of the community contexts are provided to shed light on the practices and characteristics of daily life in Epe's rural areas as a whole, and in each community. The information presented in this section was obtained

from a range of sources including primary observation, focus group meetings, interviews, and from a small number of secondary sources that include academic literature and local-level survey data. Information obtained from secondary sources and quotes during interview conversations have been referenced accordingly. All other information provided was obtained during primary data collection in the field; either through observation, unrecorded meeting conversations, or focus groups. Statistical data specific to the case region at the local level is extremely limited, with only the following published sources shedding some light on the statistics that describe the region: CERUD (2006, 2009), LBS (2010, 2012, 2013). Other statistical data, specifically on the populations of the communities included for fieldwork, were obtained from the Epe local government, according to their records on file.

The most recent sources of wide-ranging data on the case region in the lead up to fieldwork — the 2010, 2012 and 2013 Lagos state household surveys — made use of samples that aimed to be representative of the state (LBS 2010, 2012, 2013). Although their data is disaggregated to indicate local level statistics, such as that of the case region, the representativeness of the samples is weaker at that level — particularly in the case of the Epe local government.<sup>17</sup> So while they are relatively reliable sources of statistical data for Lagos (particularly on population, income and expenditure proportions; which is what they were predominantly used for in the development of the Lagos-LEAP model presented and used in Chapter 8), the reliability of their representation of Epe's communities may not be so strong, and had to be treated with caution. For example, if by reason of accessibility, data collection was concentrated in Epe town (see Figure 6.5) — which is more akin to peri-urban Lagos in population density, infrastructure, services, markets and lifestyles than the more rural and remote communities this research focuses on — then the socio-economic, cultural, technological, and behavioural data obtained could be unrepresentative of the more traditional cultures of the region's rural areas.

In addition, some design issues were also observed with the Lagos state household survey data; for instance, in the use of multiple choice questions that failed to make provision for multiple selections where relevant — such as when households stack their energy services. Thus, given the misrepresentations that can be present not just with limited secondary data,

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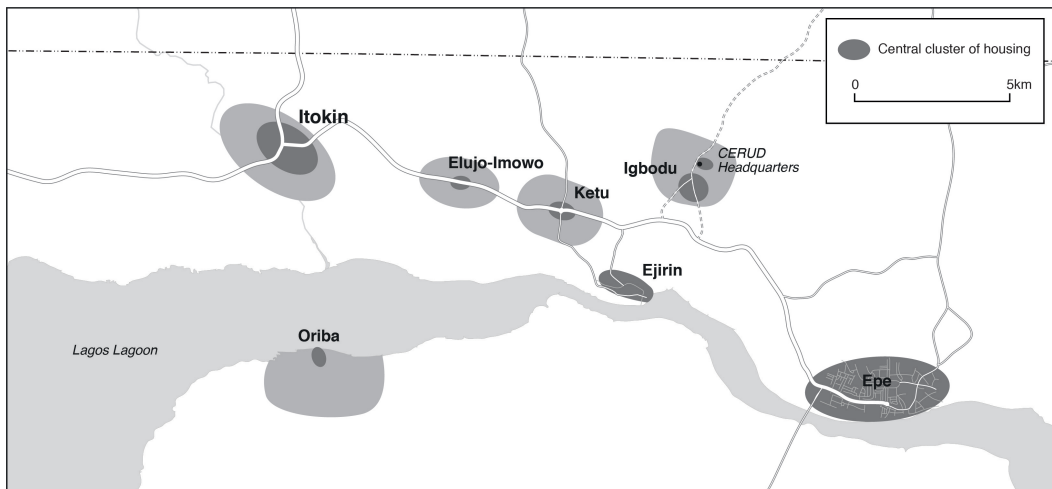
<sup>17</sup>For example, the Lagos state household survey 2013 utilised a two-stage stratified sampling technique that accounted for all local governments in the state, and further divided each local government into 10 to 25 wards from which respondents were selected (LBS 2013). While the survey specifies a resulting sample that is “representative of the study population in line with the geographical spread and the household socio-economical strata”, there are a couple ways in which the sample obtained for the Epe local government area may not be representative of the region (idib., p. 12). Firstly, the application of ‘probability proportion to size’ in determining sample sizes used, was applied at the local government level, not the individual wards in which the LGA was divided, thus opening the final selection of respondents to be disproportionate across the wards due to reasons including, for example, accessibility (SSC 2001) — which is difficult in the more remote and dispersed communities of the LGA. Secondly, the final sample for the Epe LGA was 61 against an estimated 2012 population of 390,060; the power of which (in terms of proportion only) was significantly weaker than samples obtained for other local governments. In 1999, a local survey recorded 313 communities in Epe, thus a sample of 61 will be difficult to describe the population (Yusuph & Nwabuisi 1999).

but also from local informants and focus groups (see Chapter 5), it was useful to rely on the mix of these methods as a means of triangulation to verify the data informing the case region's context. Statistical data observed for Epe in any one of the state surveys was also cross-examined with surveys from the other years as a means of verifying the reliability of the data.

## Geography

The three least populous local government areas (LGAs) of the state — Badagry, Epe, and Ibeju-Lekki — are also the three largest LGAs by land mass; representing a combined 58 % of the state's geographical coverage by land (CERUD 2006, LBS 2013). With average population densities as low as 38 persons/km<sup>2</sup>, they host the most dispersed set of communities and livelihoods in Lagos. The above regions capture a context within the state where community development and household lifestyles are at a more primitive stage as compared to metropolitan Lagos. The Epe local government in particular, presents an interesting area from which to select the researched communities, given the variance in community characteristics that can be found within its borders.

**Figure 6.5:** Map of the case study region (portion of the Epe LGA, Lagos)



*Source:* Author's depiction

*Note:* Region on the map labelled 'Epe' is 'Epe town'.

Road running west from Epe town, is the Ikorodu-Epe road.

Road running south from Epe town is the Lekki-Epe road.

Epe is separated by the Lagos lagoon from its west to eastern border, with coastline communities either side of the water body situated around swampy marshlands, which provide naturally fertile soil for agriculture (CERUD 2009). The segment north of the lagoon, connected to mainland Lagos and wider Nigeria, is bordered by Ogun state in the north and the east, and the Ikorodu LGA of Lagos in the west; while much of the southern segment is surrounded by water, connected in the south to Lagos Island bordering the Ibeju-Lekki LGA.

### ***Social and Economic characteristics***

The profile of the region — reflecting a long history of small holder farming, fishing, and trading (Yusuph & Nwabuisi 1999) — provides added challenges to physical development than is found in other areas of the state. The dispersed populations, and marshy terrain, amidst vast swathes of forests have made the installation of critical infrastructure for development more costly and technologically demanding (CERUD 2009). The result has been a lack of access to basic services and economic opportunities, with many of the younger generation leaving the region to seek work in urban Lagos.

**Figure 6.6:** Landscape in the Igboodu community



*Source:* Author's picture (September 2013)

Industrial activity in Epe is limited; though it comprises one of the three main mining zones in the state for oil sands and other solid minerals (PwC 2015) — which can frequently be seen transported along the Lekki-Epe road and the Ikorodu-Epe road towards activities in metropolitan Lagos (see notes under Figure 6.5). It has few market areas — namely Epe town in the east — which make up the major hubs of daily economic activity in the region; where products and services characteristic of a small town centre can be located in accordance with the needs and practices of consumers in the surrounding areas.<sup>18</sup> These market areas have led to the development of smaller community vendors that have sprung up within convenient community locations; where products are sourced from the market hubs within Epe and in some cases outside the LGA, to be sold at the convenience of community residents.

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<sup>18</sup>The nature of rural Lagos life ensures that markets consist of sales of daily amenities in the form of water (for bathing, cooking and drinking), household fuels and technologies (including private generators), consumables in the form of fresh farm produce and manufactured goods; in addition to services in the form of banks, hairdressers and other artisanal activities.

**Figure 6.7:** Petit-trader in Ketu community and author (left)



*Source:* Author's picture (November 2013)

The region has benefited from the growth in Nigeria's telecommunications sector, as increased use of mobile telephony has enhanced productive activities and social relations. It is estimated that 74 % of Epe households make use of at least one mobile phone (LBS 2013). This has also had knock-on effects on income generation in the rural communities, as increased use of mobile phones has led to sales opportunities for community petit-traders engaging in the sale of top-up vouchers and telephone accessories as part of their product range. Outside of the market hubs, in communities scattered to the west of Epe town, most households are self-employed. Smallholder farming, petit-trading and public service are the dominant forms of occupation in these regions, with many households and individuals combining a mix of these activities in a bid to sustain their livelihoods CERUD (2009). Smallholder farming operations largely involve the agriculture of seasonal vegetables and other subtropical crops (such as cassava, maize, and rice) for subsistence and income generation on owned or rented lands (Yusuph & Nwabuisi 1999, USAID 2010). Instances of livestock farming are largely limited to institutional farming organisations; with few residents engaging with small-scale poultry and fish farms. The riverine communities include fishing in their livelihood activities for subsistence and income; and households also engage in logging and hunting (focus group 2013, personal communication, 4 September; Yusuph & Nwabuisi 1999).

According to data on household expenditures in Lagos state, it is estimated that 24 % of Epe residents live in relative poverty (national poverty line <\$2.5 per day (2010 international prices)) LBS (2010). As is found in Lagos and other areas of Nigeria, the primary form of

borrowing adopted by households in Epe are from family and friends (respondent shares between 47 % and 86 % across multiple Lagos state household surveys) (LBS 2010, 2012, 2013). The state surveys show that households that do not take loans do not see the point in taking formal loans and/or are uncomfortable with taking on formal debt (respondent shares total between of 81 % and 86 % providing one of the two reasons) (LBS 2012, 2013). This perception was also observed during fieldwork interviews but did not suggest an aversion to consumer financing (H11-EI 2014, personal communication, 30 October).

Estimates suggest the share of migrants in Epe is not lower than those found in metro-Lagos — where extensive in-migration provides a population composed of people from all parts of the country and neighbouring countries — nevertheless, just a little over half of the former's residents are thought to have originated from Epe (LBS 2013). The number of migrants, particularly in smaller and more remote communities, responds to the seasonality of farming activities. During the dry sowing and harvest months of the year, a temporary labour force takes residence in communities as farmers seek employees on their land. There is therefore a seasonal impact on the demand for community products and services, accommodation, and the makeup of socio-cultural activities practised; and by extension energy services (H8-K 2013, personal communication, 5 September; H7-EI 2013, personal communication, October).

Particular dynamics exist around gender roles in the public realm; but in private these dynamics were observed to vary. Across most traditions in Nigeria the husband is considered to be the primary breadwinner of the family, and this is no different in Lagos and amongst communities in Epe (LBS 2013). The smaller, less-developed communities of this case study displayed strong traditional customs, particularly during introduction, where a very formal approach was demanded; as interested men (only) in the community gathered to hear the purpose of the work to be conducted. It was suggested that there exists a stigma against women who often engaged with social activities in market places more than was necessary; whereas this was not the case for men. One female interviewee spoke of how she would rather meet her friends in each other's homes than at social venues:

“No (I don't have friends) because I don't want problem...My room is my friend (laughter)...You know when a woman is seen outside too much it's not good. I don't like trouble...My husband always plays and goes outside. He's a man...Him and his friends, they go...Any friends that I have they will come and meet me in my kitchen...Yes we'll play [socialise] together there...then everybody will go his [her] own way” (H15-IG September 2013)

In all of the communities visited, it was observed that the occupation of petit-trading was undertaken by women. While male spouses in some cases contributed towards the trading

business through sourcing or transportation of products, women took on the activity of making sales. On the other hand, it was particularly evident that only men drove vehicles, whether private or for public service; women only travelled either by walking, utilising public transport, or relying on their spouse to take them where they needed to go.<sup>19</sup>

## ***Political Economy***

Historically, the nature of rural communities in Lagos was such that traditional leaders were an important source of communication to members of the community, and thus played an important role in development works (Yusuph & Nwabuisi 1999). They are the first point of contact for government and other external private enterprises seeking to engage with the community. From focus group conversations undertaken in the communities and meetings with key informants, this was corroborated to still be the case in 2013 socio-political affairs.<sup>20</sup>

The communities visited for fieldwork have had experiences with development projects from the state; including youth training and support in farming practices, as well as in the provision of public services, in the form of boreholes and health centres. It is also common practice for these development works, such as the provision of basic infrastructure services, to stem from an underlying goal of political expedience, the generosity of a returning indigene or community leader, or spill-overs from state projects (H8-K 2013, personal communication, 5 September; CERUD manager 2013, personal communication, 5 September). What has typically accompanied such projects — undertaken out of step with budgetary scrutiny and due process — include poor service management, disappointing outcomes leading to a lack of trust between communities and the government, and unrealistic expectations by the local people on what is required for development and what it should look like.

There exists a general sense of neglect felt by the locals from the government as was communicated by a number of community leaders in the majority of the communities visited — as well as households — as a result of their experiences (community chief-Igbodu 2013, personal communication, 5 September; community development officer-Oriba 2013, personal communication, October; H7-EI 2013, personal communication, October; H13-IG 2013, personal communication, October). The situation suffers from opposing perceptions;

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<sup>19</sup>It is unclear whether the roles men and women take regarding the household livelihoods are indicative of a power structure within the communities, or shaped up by default as a result of age-old customs; where it is expected that a man goes out as the breadwinner for the family, whilst the woman stays home to look after children and the elderly. The example in the main text can be due to the fact that women maintain access between their homes and their stalls for petit-trading throughout the working day; where potentially the decision to engage in the productive activity stemmed from an added opportunity for income whilst conducting her daily activity of looking after those at home. Whereas men, who traditionally travel around during their income generating activities are by default, best-placed to obtain driving knowledge and means to allow them move more efficiently.

<sup>20</sup>Communication in Lagos' rural communities is often facilitated through periodic meetings chaired by local chiefs or scheduled by specific groups or tribes; the latter of which varies by community. Every community however, has a traditionally elected leader (the 'Oba'), whose cabinet is made up of a number of chiefs ('Bale') according to the zones within the community. A part of the duties of the leadership is to source development programmes for the community, and play a crucial link between the government and the people.



where government officials consider rural locals to exhibit both positive and negative attitudes towards change, whereas locals cite a lack of support and inefficient services as reasons for slow transitions. For example, CERUD officials accuse locals of being apathetic to the adoption of fertilizers and health centres, instead choosing to rely on their natural climate for productivity in the former, and traditional medicinal practices in the latter.

“During a development agency sponsored project to promote the use of fertilizers, they were not encouraged [convinced], refusing to adopt the use of fertilizers, claiming that God has always provided rain for them. They were only interested in finding out where they could sell any of the products the project was ready to hand them for free” (CERUD manager 2013, personal communication, 5 September)

On the contrary, one of the local chiefs, advocating on the need for agricultural stimulants to boost productivity and efficiency in the cultivation of land in the state, argues that support is only really seen in the north of the country, where the natural climate is not as conducive.

“There is not enough support from the government for Southwest farmers that will allow them to be able to afford and utilise such resources” (community chief-Igbodu 2013, personal communication, 5 September)

### ***Energy and daily life***

In order to examine the behaviours and service transitions of households in the communities researched, it is useful to consider the nature of their daily routines and practices. A typical day starts at the break of dawn (circa 6am) for most residents; where the children who attend school make their own way to school, as working adults prepare to make their way to the farm, sea, or forest. Those engaging in non-farm work have a more flexible start to the day, as community market clusters, where petit-traders have their base, are usually located within a short walking distance of their homes; therefore, commitments and activities at home influence proceedings.

The dynamics of a household — which on average can range in size anywhere between 3 and 10 people, but for extreme cases<sup>21</sup> — are influenced by factors such as the marital status of the household head, the nature of their residence in the community, and hence their home-ownership status and residence type. In rural areas of the developing world a higher number of persons in the home can be desirable, as the family benefits due to the greater need for manual labour in the undertaking of daily activities (Bhandari 2013). In communities with greater economic activity the houses are typically brick-layered or mud-houses; while in the poorer communities, a large number of households have their entire

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<sup>21</sup>A small number of households cited household sizes in the region of 15 to 19 persons, comprising multiple generations living at the same premises.

structures largely based on straw-thatch. Through personal observation and experience, it was identified that none of the structures are designed to make good use of daylight, and rarely facilitate quality ventilation. As a result, residents spend most of their days outside built structures; whether it is at the home, or at the work place.

**Figure 6.8:** Straw-thatch house in Oriba community



*Source:* Author's picture (October 2013)

School hours on average run between 8.30am and 4.30pm, at which point children tend to meet their parents at home or the work place, before undertaking their necessary evening activities. Some of these activities include the gathering of fuelwood for cooking purposes (see Figure 6.9). There is a desire, and difficulty, for households to find the right balance between sending children to school and for children to undertake farm and household activities; with a number of interview participants highlighting the importance of children learning the family livelihood trade of farming, but equally acknowledging the need for formal education for their children (H15-IG September 2013, H13-IG September 2013, H11-EI September 2013, H10-O November 2013). How these and other non-energy livelihood considerations impact the energy behaviour of households will be examined in Chapter 7. Because afternoons are spent away from the home by most farming households, it has been noted as common for many of these households to engage with only the breakfast and dinner meals of the day. In the afternoon, snacks, fruit and other foods that do not require cooking — such as drinking garri (processed cassava flour) — are typically consumed.

Depending on the time of year, sunset in Southwest Nigeria, ranges between 6 and 7pm, however twilight is no longer sufficient between 7.30 and 8.30pm; at which point all farming activities cease. At night time, some community traders continue sales activity, while others close and gather with the family in their homes for evening meals, and other activities. Other residents, particularly men, sometimes engage in night-time fishing and hunting for commercial and/or subsistence purposes, or utilise the night life at burgeoning town centres

**Figure 6.9:** On route to Egansoyindo community, south of Elujo-Imowo



*Source:* Author's picture (September 2013)

(such as Epe town) or communities with larger hubs within Epe.<sup>22</sup>

In support of the above daily activities are a range of energy services which are considered by residents for both their home and productive activities, sometimes in unison; given that the majority of their energy services are off-grid and can cut across end-uses for the home and productive activity. Table 6.3 provides a breakdown of the range of these energy services according to their function and purpose; while a brief description of typical behaviour respective of the activities described above, is subsequently provided.

Just as is the case in Lagos and wider Nigeria (see Section 6.3.4), kerosene is the most commonly used fuel in the communities visited. This is because it meets both lighting and cooking energy services. It is used for lighting purposes at night time or early mornings before daybreak by households and businesses alike. It is also used for cooking either directly with the kerosene stove, or in support of fuelwood cooking as a fire-starter — the latter of which is common practice for fuelwood cooking in the region. Residents who own their homes as detached structures situate their kitchens outside; in some cases with a roof to assist cooking during the raining season. Some of those who rent their homes have shared communal kitchens only, situated inside the building structure, where they perform their cooking tasks indoors. On occasion during raining season, rainfall damages outdoor kitchens, forcing households to undertake cooking practices indoors. These dynamics have been cited to influence the mode of cooking utilised by a household, because indoor cooking is typically not performed with traditional wood burning stoves.

During the day, the need for energy services is typically a demand for those engaging in productive activities or community public services; for example, in the operation of pro-

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<sup>22</sup>Locals generally cited that there was not much by way of night life in their communities as compared to other parts of Lagos, except for certain locations in Epe. Many men cited spending time at home with families or at television entertainment spots with friends.

**Table 6.3:** Household energy services in communities visited

Energy Service	Fuel and Technology		
	<i>Primary Energy Carrier</i>	<i>Secondary Energy Carrier</i>	<i>Conversion Technology</i>
Cooking	Gasoline; diesel; grid	Fuelwood; kerosene; charcoal; private electricity (diesel-based only); community electricity; grid electricity; LPG	Three-stone stove; welded fuelwood stove; charcoal stove; smoking wood stove; kerosene stove; electric stove; LPG stove
Lighting	Gasoline; diesel; sunlight; grid	Kerosene; rechargeable batteries; home private electricity; community electricity; grid electricity	Kerosene lantern; torch; rechargeable lantern; mobile phone light; light bulb; street lamp; solar lantern
Space Cooling	Gasoline; diesel; grid	Batteries; private electricity (diesel-based only); community electricity; grid electricity	Fan; air conditioning
Food Storage	Gasoline; diesel; grid	Fuelwood; private electricity (diesel-based only); community electricity; grid electricity	Smoking stove; refrigerator; freezer
Television Watching	Gasoline; diesel; grid	Private electricity; community electricity; commercial electricity; grid electricity	Home television; commercial television
Mobile Phone Charging	Gasoline; diesel; sunlight; grid	Private electricity; community electricity; grid electricity	Home power socket; commercial power socket; solar lantern socket
Productive Activity	Gasoline; diesel; grid	Fuelwood; kerosene; gasoline; private electricity; grid electricity	Various types

*Note:* There was no indication of improved biomass cookstove (ICS) use among the participants included in the study.

ductive machinery such as water pumping at a borehole site, powered by diesel generators. Some businesses provide daytime cooking as part of their commercial services, and hence rely on fuelwood and/or kerosene for their operations.<sup>23</sup>

As mentioned in Section 6.3.4, households in rural areas benefit least from the subsidy on petroleum products, and are often faced with black market prices due to poor distribution channels. Around the time of fieldwork, the official subsidised price of kerosene was US\$0.31/l, down from a market price of circa US\$1/l (IISD 2012).<sup>24</sup> Households in the communities visited purchased their kerosene at a cost no lower than US\$0.64/l, and often

<sup>23</sup>Some establishments providing consumable products such as the sale of cold beverages, choose to operate a freezer as opposed to a refrigerator, in a bid to maximise the fuel-efficiency of their energy consumption. Using a freezer allows them to operate their generator at night-time only, when they demand other energy services, such as lighting. They freeze beverages overnight, allowing beverages to remain cool for much of the day when demand is high, without having to operate refrigeration services during the day.

<sup>24</sup>These prices were in place for the period 2013/14, prior to the 2016 removal of the gasoline and kerosene subsidies.

paid as high as US\$1.27/l during purchases from community vendors. The forest regions of Epe are a major source of fuelwood; harvested to be sold in neighbouring Ogun state and metropolitan Lagos. Although for local households, it is freely gathered for consumption. Despite legislation to protect some forest regions of Epe and other regions of the country, weak implementation encourages illegal and unsustainable logging activities and fuelwood harvesting (Faleyimu & Agbeja 2012).

Since gasoline is sold only at towns with gas stations, it is typically purchased close to the official subsidised price of US\$0.62/l (IISD 2012); except for instances of fuel shortages. Similarly, modern fuels and conversion technologies, such as LPG and its burner — that are scarcely used in communities — are only sold in trade-towns like Epe town and Ejirin. The costs for such an energy service relative to competing kerosene and fuelwood-based cooking services are particularly prohibitive for poorer households; where a 3 kg LPG burner can cost circa US\$35, with refuelling costs of US\$7.6 (H50-IG 2014, personal communication, 11 November; Accenture 2011a). It has been estimated that in some areas of Nigeria — such as urban regions where fuelwood and charcoal must be purchased — LPG is competitive in terms of cost per service rendered due to the inefficiency of traditional fuelwood and charcoal conversion technologies, and the prevalence of black market kerosene prices (Accenture 2011a). However, these conditions do not apply to Epe communities given the availability of freely collected fuelwood and charcoal fuels acting as cheaper alternatives to LPG, with its high capital outlay.

At the time of fieldwork, there were no street lighting services around the western region of Epe where the communities resided. Illumination at community market areas is typically facilitated by minimal outdoor lighting on private structures. The communities have no road network within them, apart from makeshift pathways between built structures providing access routes. Therefore, night-time movement is usually enabled by the use of lanterns and torches. In the communities connected to the grid (Igbodu, Ketu, and Itokin), residents scarcely rely on or expect electricity services; with many citing electricity unavailability that can last months (see Section 7.2.2). Survey data from 2012 and 2013 respectively show that 85 % and 100 % of residents in Epe receive electricity for no more than 5 hours in a day, when electricity is provided (LBS 2012, 2013). If electrical energy is desired for night time activities, residents make plans to fuel private generators or access privately generated electricity services from a nearby location (such as a neighbour) (see Figure 6.10). These activities include — in addition to electric lighting operation — watching television, mobile phone charging, and operating fans.

In examination of the insights on consumer behaviour and perceptions; it is important to recognise that the definition of what constitutes modern energy service to academics and practitioners differs from that of the locals interviewed. Indeed, depending on the energy

**Figure 6.10:** Typical portable gasoline generator used by low income households in Nigeria



Source: NauticExpo (2018)

Note: The Tiger portable gasoline generator, colloquially known as ‘I better pass my neighbour’, is the archetypal private electricity generator used by low income households in Nigeria. It is typically a 0.65 or 0.7 kVA gasoline-fuelled generator with DC supply.

service in question, a particular fuel can be considered both traditional and modern. For example; household kerosene is not considered a modern energy fuel by the international community, though it is a non-solid fuel used for cooking. For those that make use of traditional fuelwood cookstoves as part of an energy stack with the kerosene stove for example, the former can be the primary cooking energy service; and therefore, kerosene stove ownership (to those that do not own one) or primary use of a kerosene stove for cooking is held by many in high regard. However, kerosene is also used for lighting services, and facilitates the combustion process during fuelwood cooking, as mentioned earlier. All three uses of kerosene make it ubiquitous in all of the communities, and explain its marketing within most communities. But the kerosene lantern, being unclean in its use and providing among the lowest quality lumen of all lighting services available, is considered a traditional energy service (business as usual or practices of the past) that is beneficial to displace.

Essentially, the local perception of traditional and modern energy is influenced by a range of factors, such as the perception of costs, technical performance, the observed social status of owners, the prevalence of use within the community and in more affluent regions of the country, and others; all of which influence a local view of energy services that should be improved upon (traditional) and can be aspired to (modern). These perceptions have important implications for consumer behaviour and attitudes towards energy services. It is therefore useful to take note of energy service perceptions of the academic and practitioner community (see Section 2.3), as well as those of local households when categorising energy

services discussed in Chapter 7; as shown in Table 6.4 for the latter group. The voices of interviewed locals, which shed further light on these perceptions, are presented in Chapter 7.

**Figure 6.11:** Locally-constructed battery-powered lamp ‘Ojutinepa’



*Source:* Author’s picture (October 2014)

*Note:* Ojutinepa is considered a traditional form of lighting by locals, despite its reliance on batteries — which are also used by modern-perceived branded torches and lanterns — because of its poor durability, cheap craftsmanship and relatively poor illumination.

**Table 6.4:** Energy service definitions used in analysis

Traditional energy services	Kerosene for lighting; kerosene lantern; unsustainably harvested biomass; fuelwood stoves; fish smoking wood-stoves; charcoal; charcoal stove; charcoal iron; ojutinepa
Transitional energy services	Kerosene for cooking; kerosene stove; gasoline for electricity generation; diesel for electricity generation; private gasoline generator; community generator (diesel-based); home appliances powered by fossil fuel-based private generator (e.g. fan, television)
Modern energy services	LPG; LPG stove; reticulated electricity (grid and mini/micro-grid); stand-alone renewable electricity; solar lantern; home appliances powered by reticulated or stand-alone renewable electricity

*Note:* These definitions were not directly categorised by the participants, but are based on observed perceptions in the field.

The various capacities with which different households in the selected communities engage with these energy services to meet their daily and weekly livelihood needs, bring forth complex dynamics that determine energy behaviour and the considerations that predicate them. It is in the exploration of these dynamics that this research seeks to answer research question 2. This section discussed some of the important features found in the communities and wider Epe. The sections that follow will provide a few distinctive features about each community that influence the lifestyle and energy behaviours of their respective households.

### 6.4.1 Igboodu

All the communities included in research are located west of the central market in Epe town. Igboodu is the closest of the communities (see Figure 6.5), and is situated relatively close to the Ikorodu–Epe road; which links Epe and metropolitan Lagos. Despite the poor state of the Ikorodu–Epe road, which impacts the efficiency, safety and speed of vehicle travel, there is relatively good access to the community. The community comprises about 1500 residents of various ethnicities, engaging predominantly in agriculture for commercial and subsistence purposes. A fair number of households are situated close to the community access point; at the centre of which, is a handful of small vendors engaging in petit-trading.

The Igboodu community has been actively involved in the development activities undertaken in rural areas by the government parastatal, CERUD. The decision of some community members to sell land to the government, for which to situate CERUD's premises, has increased interaction between the community and the government. This reality has been accompanied by direct and indirect benefits to the community; such as selection for participation in pilot training projects, as well as the development of road access from the Ikorodu–Epe road leading to the community.<sup>25</sup> Nevertheless, the unplanned nature of development in the community is characterized by services that have been planned inefficiently and/or poorly managed (such as water service provision), amidst a policy adopted by community leaders to encourage locals in the non-equitable sale of their lands as a means to bring about community development.<sup>26</sup>

### 6.4.2 Elujo-Imowo

The Elujo-Imowo community is the smallest of all the communities researched, situated along the Ikorodu–Epe road, between Itokin and Ketu. Though this provides ease of road access, the community is bereft of central grid electricity infrastructure; with residents harbouring feelings of injustice as they observe daily, the presence of transmission lines and poles that have bypassed their community unto neighbouring communities — as stressed by a community leader during early interactions.

“Lack of electricity is a real problem for us...we are ready to accept anything beneficial, but we need the grid electricity” (H7-EI September 2013)

To offset the lack of grid infrastructure, residents are forced to rely on 3 hours of community distributed electricity provided once every three days, via a diesel generator setup by the

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<sup>25</sup>This renewed level of accessibility serves to benefit the ease of access for construction purposes, and/or personnel and businesses with private vehicles. It does not serve to benefit the wider population in the form of public transportation, who still have to walk to the Ikorodu–Epe road before accessing paid-transport. However, motorbike transport service is available directly from the community for travel by 1 or 2 passengers.

<sup>26</sup>The ill-managed transactions between locals and the government have led to disputes between the two parties. During fieldwork, strike action was witnessed, as locals — including those employed at CERUD — protested outside CERUD premises; with those employed refusing to work until they had received payment of the monies still owed to them by the government, as part of the transaction for the land upon which the CERUD site was constructed.



community's development association.<sup>27</sup> Those who can afford it, have in addition to this, private gasoline generators. This practice of shared community electricity provision was facilitated by the arrangement of the community; where the majority of its circa 100 residents live in a cluster of households near the community access point.

Given the small size of the community, there is limited benefit against the costs of situating institutions such as a school or a health clinic within its premises; which can be accessed at larger communities in the region. Importantly however, the community lacks the presence of economic activity for fast-moving consumer goods (FMCG) within its borders; i.e. absence of petit-traders providing access to daily household goods. Although, some households sell food and drink items on their doorstep, such as bread, vegetables and beverages (H7-EI September 2013). A little under an hour's walk is necessary to access the nearest community with stalls selling daily amenities, if transportation services are unavailable.<sup>28</sup> The only productive activities undertaken in the community are farming and small-scale processing of farm produce, to be transported and sold at trade-markets.

### 6.4.3 Itokin

At the centre of the Itokin community is a roundabout connecting metropolitan Lagos, Ogun state, and Epe town. This provides a higher flow of traffic through the community relative to most other Epe communities, and has contributed to it holding the most vibrant market centre of all the communities included for research. The community has become known for its retail market which is set up once a week on a Sunday; as traders from metropolitan Lagos and Ogun state set up stalls to provide a wide range of products. This has had a significant impact on the spending practices and technological access of the circa 6000 community residents, as is discussed in Chapter 7.

As its daily market centre has developed, farm work is no longer an exclusive vocational activity. Many of the middle-aged residents pay greater attention to engaging with civil service, and petit-trading; the latter is particularly the case for migrants, who have limited access to land. Some residents continue farming in addition to other economic activities, but with less emphasis on the former. One informant emphasised, that smallholder farming activities is a thing for the older generation nowadays, who continue with what they know best (community youth development officer-Itokin 2014, personal communication, 30 October). However, the state government has actively engaged with this community to address youth unemployment through rice farming programmes that include; rice production training, and

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<sup>27</sup>This form of electricity provision is classed as having no access under the Global Tracking Framework (see Table 2.2), as is much of the grid provision provided across various areas of Lagos state.

<sup>28</sup>Due to the poor state of the Ikorodu-Epe road at the time of fieldwork exacerbating irregular public transportation services, waiting times at informal bus stops can be up to 2 hours (LBS 2010, 2012, 2013). However, the increasing access and use of mobile phones have made it possible to build relationships with motorcycle transportation services and request their services as demanded; this has also benefited transportation of farm produce.

technical, advisory and financial support for start-up farming operations (Lawal 2012). Due to the increased traffic of people and products this community experiences it has developed a hub for taxi services; and thus, a small demographic of those employed as taxi drivers that is seldom found in other communities.

Due to its accessibility and opportunities for work relative to other Epe communities, residents of Itokin are less estranged to activities in metropolitan Lagos and urban areas of neighbouring Ogun state. Traders often journey to these regions and migrants have greater opportunity to make periodic visits home via these routes. Across all the communities researched, the opportunity for, and undertaking of, overseas travel is a feature of the more prominent members of the community; such as Chiefs. Therefore, aside from the information and awareness provided by radio technology and television services (private or communal), and from community leaders (LBS 2013), information — particularly on products and services — often travels to the more primitive communities via neighbouring trade-communities such as Itokin, when it gains exposure to new developments via community traffic or from the travels of community personnel.

#### **6.4.4 Ketu**

Along with the Itokin community, Ketu is another community that has benefited from its geographical location; situated around crossroads that connect Ogun state in the north, Epe town in the east with a road route to Lagos Island, the Ejirin market in the south, and mainland metropolitan Lagos in the west (see Figure 6.5). A small group of vendors are situated at this crossroads providing consumer goods from refreshments to the cooking and lighting fuel — kerosene. The community's population of circa 5000 residents consists mainly of farmers and petit-traders. The presence of a health clinic, as well as government and privately-owned schools has resulted in a number of professionals from the above sectors residing in the community. However, health service supply issues due to a lack of funding, limited accountability and a lack of critical infrastructure such as electricity — that plague primary health service across the country (Das Gupta et al. 2003) — have led to neglect by patients and staff alike (CERUD manager 2013, personal communication, 5 September).

#### **6.4.5 Oriba**

The final community explored during the fieldwork process is the Oriba community, which is distinctly different to the other communities involved, in that it is situated south of the Lagos-Lekki lagoon on the island segment of Epe (see Figures 5.1 and 6.5). Access to Epe communities in this region is inherently more difficult, as the nearest major road (Lekki-Epe road) is situated as far as 14km from some of the communities. Oriba is very much a remote community, with approximately 50 dispersed villages as clusters of a handful of settled houses. It is one of a number of riverine communities in the state with unreliable

access across the lagoon (due to marine litter) from mainland Epe in the north, as well as informal road access through treacherous terrain from the Lekki–Epe road in the southern region of the state (see practical difficulties discussed at the end of Section 5.3.2).

Exhibiting strong traditional practices (see Section 5.3.2), the community is characterized by a lack of access to public services, including grid electricity access. Contrary to Elujo-Imowo, it has a history of experience with the state government on public service projects; in the provision of street lighting, solar water pumping, health centre, as well as primary and secondary school developments — all of which have been unsustainable.

**Figure 6.12:** Unsustainable community solutions implemented by state government

(a) Abandoned solar-powered water pumping system



(b) Abandoned community hospital



*Source:* Author's pictures (October 2013)

Given its geographical location (next to the lagoon) fishing is common practice by residents of the community, along with agriculture for commercial and subsistence purposes. Traders within the community also rely on challenging transportation services across the lagoon to source products from Ejirin and Itokin; including the sourcing of household fuels for sale to fellow community residents. This has major implications for energy practices within the community, as constrained availability means they pay a premium on fuels such as kerosene. Recreational activity within the community is particularly low in Oriba, as informants highlighted that options were limited for social interaction and entertainment, save for sport and in-home activity (community development officer–Oriba 2013, personal communication, October).

**Table 6.5:** Summary of community characteristics

<i>Community</i>	<i>Population</i>	<i>Community market place</i>	<i>Community electricity service</i>	<i>Other public services</i>	<i>Access to Epe town (or other major trade market)</i>
<b>Igbodu</b>	1500	Stall vendors	Tier 0 grid	Unreliable water pumping	16 km dilapidated road access
<b>Elujo-Imowo</b>	100	Unavailable	Tier 0 micro-grid	Periodic water pumping	7 km dilapidated road access
<b>Itokin</b>	6000	Multi-service market place	Tier 0 grid	Private water pumping; school	>25 km dilapidated road access; in-community weekly trade-market day
<b>Ketu</b>	5000	Stall vendors	Tier 0 grid	Non-operational clinic; school	15km dilapidated road access
<b>Oriba</b>	50 dispersed villages	Stall vendors	Tier 0 micro-grid	Non-operational clinic; non-operational school; non-operational water pumping	>14 km informal road access; unreliable river access

## 6.5 Conclusion

Nigeria is a country endowed with vast resources — natural and human — but a post-independence history characterised by war, corruption, and economic instability has left a legacy of underwhelming development that can be seen in the many inequalities found at various levels of its society; inter-state and intra-state. Across multiple sectors that are critical to a functioning society — from land tenure to social protection, to the energy and natural resources sector, and the education and vocational training sector — a lack of clear roles and responsibilities ensure uncoordinated and ineffective activities, with limited room for accountability. The culminating result of these issues on the nation’s populace is that the wages of the average Nigerian struggle to compete with the cost of living; basic amenities, including energy services, are difficult to access. In Lagos, population pressures have left many with insecure living conditions, and limited opportunities; and as is often the case, the poor are affected the worst. Similar to other rural areas of the country, parts of rural Lagos remain primitive and underdeveloped. The five communities selected to be studied epitomise the frustrations of the people amidst varied prevailing circumstances. This diversity in community circumstances make for a broad breadth of insights when answering research question 2.

The environment in which Epe’s households make their energy decisions — from macro influences to micro influences — promotes uncertainty. Chapter 7 will discuss what we can learn from the interactions between this scene of uncertainty and the revealed behaviours of households over time. Chapter 8 will channel some of the contextual features presented in

this chapter and explore scenarios relevant to Lagos and Nigeria, to observe possible future household energy transitions in the state using the innovative Lagos-LEAP model.



## Chapter 7

# Local Realities of Energy Access Transitions

*What do the lived realities of households in rural Lagos reveal about the energy decision-making of the energy poor, and the drivers of sustained behaviour change?*

**Research Question 2**

## 7.1 Introduction

Chapter 6 introduced the macro to micro context within which, an exploration of the nature of energy service transitions was undertaken; a necessary backdrop in a bid to understand the behaviours and perception of locals in rural Lagos. This chapter uses the voice of locals on detailed aspects of their energy behaviour, from monetary expenditure through to practical application, to present and discuss findings from the case study.<sup>1</sup> The insights will be discussed in view of the concepts and framework coming out of Chapter 4 on household energy decision-making and the nature of household energy transitions in the developing world respectively. In answering research question 2, discussions will reveal, inter alia: the practicalities behind the energy decision-making of the energy poor; why energy stacking happens; and what is necessary for sustainable complete transitions (substitution) to modern energy services. Findings reinforce the usefulness of acknowledging the centrality of livelihoods in energy access activities, and develop explanations from the framework developed in Chapter 4 for explaining the different types of energy poor transitions.

The rest of the chapter is structured as follows: Section 7.2 examines the role of a household's daily activities, livelihood resources, experiences, and perceptions in shaping their energy decision-making. Section 7.3 uses insights from the field to examine the explanation posed in Chapter 4 on household energy access transitions, to reveal what is necessary for substitution transitions to modern energy services. Section 7.4 suggests some actions for Epe, Lagos and Nigeria in bringing about sustainable transitions to modern energy services, before Section 7.5 concludes the chapter.

## 7.2 The energy service decision-making of the energy poor

With the help of frameworks put forward by researchers such as Kowsari & Zerriffi (2011), and Van Der Kroon et al. (2013), Chapter 4 proposed that there are a range of factors (those of a personal nature and of the environment in which households reside) that interact in a complex manner to determine the energy-related decisions made by a household. Indeed, the energy-decision grapples with considerations regarding the primary fuel, final energy supply, the conversion technology, the energy service, and the basic desires of the individuals in the household and of the decision-maker (see Figure 4.8). The social-energy interaction also involves numerous engagements (referred to in Chapter 4 as modes of consumption or means of consumption) which in some cases may not be directly involved with final energy use but

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<sup>1</sup>The interviews recorded for this work were transcribed verbatim. Due to the use of colloquial English (of a form specific to the region) by a number of respondents and the translator, as well as participant responses to questions that hold the context of the answer given, square brackets and parentheses (curved brackets) are often used in quotes to clarify the meaning of certain texts and to complete the full meaning of an answer respectively.



are still part of decision-making (e.g. energy carrier *purchases* or technology *maintenance*). All these factors present a plethora of influences to consider, which households are very unlikely to process in their totality. Thus, it was postulated that the energy decision-making of the energy poor at a given point in time is dependent on the trade-offs between the urgency of an activity to be achieved by energy consumption, the existence of options (technologies and fuels) to fulfil that activity, and the livelihood resources available to the households and any constraints they present (see Section 4.4). How these trade-offs might take shape in reality, and the extent to which different interactions are considered and influential in decisions, is what this section seeks to reveal from the insights obtained in the field.

The section will be organised into subsections that capture two main areas of energy service decision-making that are interrelated but reveal different influences: (i) the decision to acquire a fuel and technology combination; and (ii) the decision to make use of a fuel and technology combination.

### 7.2.1 An accessible option for acquisition

#### *Available for acquisition*

One area of energy decision-making involves the *acquisition* of fuels (energy carriers) and conversion technologies. It is influenced by the household's accessibility to the energy carrier and conversion technology, the need and/or desire to make use of these components to fulfil an energy service over the short or long term, and the practicalities that govern them. For the purpose of examining household acquisition behaviour, particular attention is given to repeated transactions, as opposed to one-off transactions; as the former is of greater complexity and can reveal more about the varied behaviours of households under different scenarios, and over time. Transactions of this sort are associated either with energy carriers or technology paid in instalments over time.

It was observed that 73 % (22 of 30) of all farming households interviewed (i.e. having at least one member of the house engaging with crop, livestock or fish farming), made use of fuelwood for cooking to some extent; either exclusively, or as part of a stack of cooking energy services. On the other hand, only 30 % (11 of 37) of non-farming households made use of fuelwood for their cooking energy service. Although fuelwood is available for purchase at some community markets, it was freely acquired by the majority of interviewees that cited its use.<sup>2</sup> Therefore, there is limited room for monetary explanation of the nature of its use or otherwise. Moreover, there was no correlation between the incomes, expenditures and observed living conditions across those that made use of fuelwood vis-à-vis those that did not.

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<sup>2</sup>Journeys from home to fuelwood source can vary considerably in length of walking time. Some households cited collection sources to be nearby (H41-K; H20-IT); while others cited an hour's journey (H11-EI).

There was also no explanation on its use or non-use being based on preferences of particular household groups. Most households acknowledged discomfort with fuelwood emissions during use; some households highlighted its superiority over other energy services on the taste of food or length of preparation time, whereas the reverse was true for other households, without any correlation to household characteristics. This variation can be expected since factors such as taste can be very personal attributes based on habits and the history of a household, and are unlikely to be explained by shared social and economic characteristics. There was an acceptance that fuelwood cooking with the traditional three-stone or artisanal welded stoves was — in terms of status and health — an inferior mode of cooking, but households made use of it nonetheless even when they also used other fuels as part of their stack of cooking energy services.

However, the higher dependence on fuelwood by farm households provided the first indications that *vocational activity* was an important determinant of energy carrier acquisition decisions, and thus energy service use, because a participant's daily activities are shaped largely by their occupation or vocation.

## Farmers

Fuelwood is harvested and gathered in forests around the vicinity of farm plots where farmers spend a notable amount of their days. This makes the fuel available to them, and since it is free, it is also affordable. Whereas for non-farming households their days are spent in a manner not conducive for allocating time to collect freely available fuelwood which gives it a very different availability profile. The process of fuelwood collection is arduous and draws from the natural (stock of community fuelwood resources) and human (time and energy) livelihood capitals. Alternatively, acquiring cooking energy carriers such as kerosene largely drew from the economic capital of households, because with the aid of road infrastructure (physical capital) — although dilapidated — it is available from community vendors.<sup>3</sup>

For this reason — as well as the relatively conservative payment packages for kerosene purchases (community kerosene purchases that vary between US\$0.64/l and US\$1.27/l can be purchased in bottles as small as 50 cl), the quick transaction process of purchasing kerosene, and the difficulty of fuelwood cooking in the rainy season — all but one household (H59-K) owned a kerosene stove; even when it was not in use due to reasons of preference (H15-IG, H33-IG), unaffordable consumption (H23-K), or when it served as the secondary cooking energy service to traditional fuelwood cooking.

In terms of fuelwood acquisition the relevant livelihood capital during decision-making, from those cited above, is human capital, because there was no evidence that households

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<sup>3</sup>Although kerosene consumption is also related to natural capital, it is unrelated to the communities in discussion because the environmental consequences of kerosene's life cycle up to the point of acquisition largely occur outside the communities.

were cautious about the risks associated with unsustainable fuelwood harvesting (natural capital). Indeed, only one participant raised concern about the sustainability of the practice (H12-IG). Therefore, it is not that farming households, though owning a kerosene stove, desired to trade-off more of their human capital in the form of time and energy to acquire fuelwood than non-farming households, but rather, the drain on the former's human capital was not enough to render fuelwood collection unsustainable for their livelihood. Indeed, for farming households there was enough incentive to collect fuelwood for free to meet their cooking needs — considering the positive opinions about its superior performance in meal outcomes, though it has its negatives (emissions and others) — because they spent much of their day at source already.

Essentially, while both kerosene and fuelwood are, to an extent, affordable for all households, the availability of fuelwood was suitable for farmers because they spent their days at or near the source, while for non-farming households the level of free fuelwood availability was unsuitable. For the latter, the human capital required to acquire fuelwood far outweighed the benefits because their occupations cannot efficiently coincide with long journeys into forests and time spent harvesting fuelwood, regardless of the perception surrounding its use and meal outcomes.<sup>4</sup>

This reality can be illustrated with revelations from farmers on how they integrate fuelwood collection with time spent on the farm. But it is clearly explained by participant H33-IG. She and her husband migrated to the Igbodu community from metropolitan Lagos and live in rented accommodation, which is equipped with an outdoor kitchen, making it possible to cook with fuelwood. Farming on rented land is her primary occupation while her husband works in security. As she discussed her cooking practices and looked back to practices she used in the past while residing in an urban area of Delta state, she explains why her use of fuelwood is now possible by virtue of the ease of its acquisition whereas this was not the case in the past.

“No (I did not use fuelwood back when I lived in Delta state) because my husband was working Oyinbo [non-farm] work at Delta Glass...(I was) using (kerosene) stove at that time...(But I am not using kerosene) because we are in the farm now...It's [kerosene] not fast...No (we were not able to use fuelwood when we were in Delta state)...farm (was) near, but it's [where we stayed] inside the town...it's (an) urban area...Yes (we could buy kerosene there)...No (we could not buy firewood there)...No (we could not collect fuelwood there)...It's a big town—because as we are working for Oyinbo [non-farm] work...(at) that time, me too I am working (non-farm work)...I (was using the) sewing machine...As

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<sup>4</sup>Note also that farmers, by virtue of farming operations, are already equipped with the tools required for fuelwood collection — the axe (physical capital).

we are (now) working farm work, I prefer it (fuelwood stove)...during farm work, we prefer it, but if—had it been that we are doing the Oyinbo [non-farm] work (then we can use kerosene)” (H33-IG November 2014)

The relevant question to ask is why the nine respondents from farming households that cited non-use of fuelwood for cooking purposes behaved differently to the majority. The answer lies in the organisational dynamics of these homes and their farming activities, which do not make fuelwood acquisition as feasible as it was for the farming households that made use of it. Participant H34-IT, is an elderly woman who lives with 14 other people in her home, including her husband, some of her children, some of her daughters-in-law, and her grandchildren. She is the only member of her household that still engages with farming activities, and given her age, spends less time on the farm than most other farmers do.<sup>5</sup> She noted that she previously used fuelwood for cooking activities but she and her household no longer do so, save for festive periods. Two aspects determine that she does not collect fuelwood for cooking: (i) the limitation of her strength that determine she only works mornings on her farm is made relevant by the fact that she does not hire workers to assist her activities, thus making it difficult to engage in the practice of fuelwood collection which is most efficiently conducted with the labour of two or more persons, regardless of age; and (ii) she confirms that the majority of cooking is done by her daughters-in-law whom — as well as their husbands — engage in non-farming activities: “the wives of my children cook for me” (H34-IT October 2014). Therefore, her children and in-laws are the ones that purchase the kerosene used for cooking activities in the home, even when she chooses to undertake the activity.

In another situation that sees a farmer not making use of freely available fuelwood for cooking; Participant H17-IT lives in shared rented housing based in the Itokin community that is equipped with an indoor kitchen only. Residents, and in particular landlords, are opposed to the practice of indoor fuelwood cooking, and therefore he relies on the kerosene stove. This is the same situation for a farmer, participant H32-IT; nevertheless, it is unlikely that given the opportunity he would seek to make use of the fuelwood cookstove since he cited being unaccustomed to its use, having never used it before (influence of experience further discussed later in this section). In the household of participant H45-IT the reason for non-acquisition of fuelwood is less clear-cut. She is an unmarried woman who lives with her family (in total ten persons) at their family home in Itokin. Half of them undertake work on the farm, while the other half engage in trading activities. The participant is a trader

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<sup>5</sup>A number of farmers (H59-K, H11-EI) and informants highlighted typical farming practice of crop farmers in the region to involve beginning farming activities in the morning, before taking a break in the afternoon to avoid the midday sun, and resuming farming activity in the late afternoon (circa 3pm) and concluding before dusk (6pm). Participant H34-IT however, only practised the morning session of farm work.

herself, which explains the difficulty she would face undertaking freely collected fuelwood, after she highlighted the reason for her limited engagement with farming activities: “Because of the nature of my job” (H45-IT October 2014). But she states that all members of her home share the use of four kerosene stoves. She did highlight the use of fuelwood for cooking during festivities, which allows them — like other participants that cited the same thing — to make certain foods and cook in bigger quantities. However, understanding the decision to not acquire fuelwood for the farming members of her household will require other data that is not present.

The remaining four instances where a farming household did not make use of fuelwood involved farming activities that were undertaken as part of additional income generation for residents that have other jobs (H65-K, H46-IT, H64-IT, H63-IT). These cases typically involved those that engaged with small-scale livestock or fish-farming, and whose engagement with the farm, and farm activities, was particularly different to the average crop farmer. An informer spoke of the latter: “they are generational farmers whose lives depend on their farming activities. It is part of their identity and it is seen as a source of pride to be able to go and work on the farm” (community chief-Igbodu 2013, personal communication, 5 September). This could also be seen with the previously stated importance upon which crop farming households placed on their children learning the family trade (see Section 6.4). Whereas the former, by virtue of their networks and opportunities, have been able to purchase or rent land for livestock farming. They cited hiring workers which allowed them to engage with their primary occupations, which included revenue collection employment for the Lagos State Internal Revenue Service (LIRS) and other civil service; and thus, seldom engage with manual farm labour as part of their daily activities.

### **Non-farmers**

We can also see the decision-making processes around acquisition that influenced behaviour change in the opposing direction (from fuelwood to kerosene-based cooking) to that of participant H33-IG presented earlier. A lady, participant H50-IG, comes from a background of smallholder farming in her younger days, when in the home of her parents in Igbodu. Growing up she and her siblings practised farming with her parents and their main cooking fuel was — and for her parents she says, still is — fuelwood. She cites that though now living again in Igbodu, in her own home (she spent some of her schooling years in metropolitan Lagos), neither she nor her husband undertake farming activities, and do not engage with fuelwood any longer. Indeed, because participant H50-IG is a petit-trader, her interaction with cheaper kerosene, and therefore her affordability of the energy carrier, was increased relative to the average resident of the Igbodu community. Kerosene is one of her traded products which she sells as a community vendor. She therefore makes bulk purchases of

kerosene from petrol stations in markets at Ijebu–Ode or Epe town at a lower price per litre than is sold in communities (see Sections 6.3.4 and 6.4); therefore saving on her financial capital that is traded off for the portions she uses for her household. In addition, because her periodic journeys to the market are a necessary part of her vocational activity to source her kerosene and other products traded, there are no added trade-offs from her human or other capitals (e.g. time (human capital) or transportation costs (financial capital)) to achieve the savings she makes on her kerosene purchases. Whereas, there would be much cost to her in trading the opportunity for financial resource gain from potential sales, if she took time out of her work to go to the forest and undertake free fuelwood collection. This is all despite the fact that she had previously been accustomed to its use. Quotes from her interview regarding this shift can be found in Section 7.3.3 with discussions about sustainable transitions.

There were a few other petit–traders with kerosene stocks as part of their product sales that also behaved in a similar manner (H18-IT, H21-IT’s wife, H48-IG). Some petit–traders do not sell the energy carrier, but make use of the demands of their vocational activity to acquire it at a cheaper price when they go and source the products they sell (H44-IT, H49-IG); finding synergy that increases accessibility.

Importantly, the question can be asked as to why ten of the thirty eight non-farming households made use of fuelwood when their vocational activity suggests they did not spend their days in the vicinity of the fuel’s *source*. It is worth remembering at this point that fuelwood and the traditional fuelwood cookstove, despite their ills, are widely regarded as beneficial in the outcome of foods prepared. Again, the behaviour of these households was observed to be facilitated by the relative ease of acquisition to the household; which meant that although they were not farmers, the livelihood resources of the households and/or their environment were such that it was either reasonable for them to trade off some of their relevant capitals in order to acquire the fuel they desired to use, or that the trade-off required was minimal, or synergy was present.

For example, participant H66-IT is a petit–trader who has her stall set up in the Itokin community, while her home is in the Agbowo community; located about 11 km west of Itokin. She explains how her cooking energy stack consists of three different fuel–technology combinations; the LPG stove, the kerosene stove, and the traditional fuelwood stove. Her preference is LPG due to its speed of cooking, but the relatively high cost of refill encourages her to ration its use. In particular she avoids using the fuel for meals that take longer to prepare, in her bid to maximise the amount of meals gained per fill. This approach of allocating tasks to certain cookstoves in a bid to maximise fuel economy was also observed in rural Mexico (Berrueta et al. 2008). She makes use of kerosene the most because its demand on her financial capital is not as high as that of the LPG stove. Then she notes

that she also uses fuelwood due to its relative speed and its suitability for time-consuming meals, given she does not have to spend money on it. Importantly, fuelwood is accessible to her because of the relationships she has around her home with farmers that make use of fuelwood to process their cassava into a local staple (garri); where they provide her with their excess wood fuel.<sup>6</sup>

“I’m not living here, I’m living at Agbowa...My market is here...No I’m not a farmer...I am using three types of cooking...Sometimes—I have a gas stove, that small one, that gas small one [portable 3kg LPG stove with a circa 22.5cm diameter hob]...I have (kerosene) stove. Sometimes if I don’t have money to buy kerosene or to fill my gas, I’m using firewood...This morning, I used firewood for the beans that I want to cook...so it will be fast...gas is faster than all those stoves and these things...but sometimes if I use it today, tomorrow I can use (kerosene) stove, next [day after] tomorrow my mind will tell me to use firewood stove. It depends on what I want to cook...Firewood? Ah, we have that one for [in] our area, we have sticks, so many sticks there, I don’t buy firewood...pick it and use it...because some people they do [produce] garri for our side [where we live], so I will also use from their side [their fuelwood stock], they have firewood with them” (H66-IT November 2014)

The daily routine of the lady discussed above was such that she arrived at her stall in Itokin around 9.30am or 10am in the morning, and left for home at 7pm in the evening. There is difficulty integrating this daily routine with free fuelwood collection from the farm. So unless free acquisition was provided her by virtue of her immediate environment the only other way for her to acquire fuelwood would have been to make purchases of it. Given that she attributed the lack of a need to make monetary payments for fuelwood as an influencing factor in her decision to make use of it for certain meals, we cannot be sure what her behavioural response might be if she had to purchase it. Nevertheless, in the current case she was able to draw on her social capital to acquire fuelwood and did not require trade-offs from her financial and/or human capital that would have been costlier to her for acquisition of the fuel; costs that may make its acquisition problematic.

Another participant from a wealthier home — who himself is an optician and an aspiring politician — combines his stay between his home with family in Igbodu and time in metropolitan Lagos. He stood out as the only participant interviewed to own and make use of mobile internet services with his laptop, and he spoke of how he and his family pay fuelwood harvesters to deliver fuelwood to them for use as part of their energy stack (H6-IG). Here, we see available financial resources being traded off to acquire the fuel they desired.

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<sup>6</sup>Garri is a local staple produced for sale. Smallholder farmers produce it through manual processing of cassava; part of which, includes extensive frying with the use of fuelwood, and a bespoke pan and stove.

Participant H41-K from a non-farming home, who describes himself as a “business man”, has suitable (acquisition) access to fuelwood because his home in Igboodu is surrounded by forests. He explains that fuelwood collection only requires ten minutes of their time, and even when he does not have the time for collection, his younger siblings who live with him — and crucially do not work — are given the task of collection.<sup>7</sup> In another example, participant H31-IG’s household do not engage with farming, and he is a taxi driver. However, his wife is a housewife, so part of her daily activities involves gathering fuelwood with which she cooks, and is therefore not conflicting with other crucial livelihood activities she would otherwise be undertaking. Again, participant H26-IT purchases her fuelwood from the marketplaces in which her stall is located, which makes acquisition easy for her with respect to her daily activities (there is further discussion on her decision to purchase fuelwood under the ‘Affordable for acquisition’ subheading later in this section). Participant H49-IG is part of the cassava supply chain, where she uses fuelwood in the production of garri she then sells. She buys cassava from farmers as part of her business, and thus her engagement with fuelwood is consistent (in synergy) with her vocational activity.

Some of the other non-farmers cited to make use of fuelwood, only did so during festive periods or for exclusive activities such as smoking fish; so there was no requirement for fuel acquisition to align with their lifestyle, because the decision to acquire it was a rare occurrence, as necessity for the rare activity undertaken. The importance of trading off livelihood resources during acquisition in a bid to sustain the daily livelihood activities of a household, can also be seen in the cases of Itokin residents that utilise the community-based taxi drivers as a gasoline delivery service (H58-IT, H38-IT, H44-IT, H18-IT); since the latter make frequent trips to towns with market areas that possess petrol stations. The situation reveals how *physical capital* (road infrastructure and delivery service) allows some Itokin residents to save time (human capital) in their acquisition of an energy carrier located outside their immediate vicinity. There may be other interviewees that had similar arrangements that were not shared in the interview; but nonetheless it can be true that social (capital) relationships with these drivers may be foundational to such arrangements, since trust is an important aspect of what are arrangements that lack formal contracts.

There is an Itokin-based taxi driver, participant H20-IT, whose reality tests the argument on suitable availability leading to acquisition; because the nature of his job does not facilitate favourable availability to freely collected fuelwood, yet this is a practice he engages in. He makes use of both the kerosene and fuelwood stoves for his weekly cooking needs, and explains how he quickly rushes to collect fuelwood when he comes home around 6pm.

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<sup>7</sup>This approach to fuelwood collection is one end of the scale. Those who live further away from the fuelwood source sometimes cited different behaviours. Participant H14-IG explains that fuelwood collection is arduous for her and her children, and due to this she tries to collect enough fuelwood to last them a month, and this can take her about 2 to 3 hours.



However, a deeper examination of his circumstances reveals why he is willing to trade-off part of his human capital (time and strength) even though it might seem costly. He chooses to purchase kerosene once a week at the Sunday Itokin market, where it can be purchased at a cheaper price than is offered by community vendors around the week, and then he rations its use through the week. He has therefore placed a threshold on the financial capital he is willing to forego to meet weekly cooking needs respective of all his livelihood needs. However, he accepts that this threshold is insufficient to meet all the demands of his cooking desires and therefore *must* find an alternative way to complete his weekly cooking needs. He explains, that in order to maximise the meals received per litre of kerosene used, he refrains from using the fuel for meals and cooking activities that take an extended period of time. Thus, cooking beans and the preparation of medicinal traditional herbs — both of which, for his household, are *urgent outcomes* (secondary capabilities) of this domestic energy service (cooking), and require an extended period of heating relative to other cooking activities — are exclusively reserved for the traditional fuelwood stove. He makes use of his social resources, in the collection of fuelwood from his landlord's land, which can be assumed to be nearby his rented accommodation (he cited spending a total of one hour to collect fuelwood enough to last one week). Since this is an activity he undertakes only *once a week*, and is required to meet the urgent thresholds and outcomes for sustaining his livelihood, it is easy to comprehend why the trade-off of his human capital required does not deter acquisition.

“(I buy kerosene) from retailers in the market...(Sunday) Itokin market here...I buy in gallon...750 naira [2014 US\$4.7]...Every Sunday...No (we do not buy it from community vendors during the week) we ration it...When it's finished, we have traditional method of cooking, that is we used—this—firewood...(How often I use fuelwood) depends on how the kerosene lasts...(but I use fuelwood) every week...at times, when I want to make use of traditional herbs, we call it Agbo, we normally use firewood because it takes long to cook—that's when I use firewood the most...To cook this our traditional herbs...then if I want to cook something like beans, it consumes a lot of kerosene, I'll cook that one on firewood...It depends on the duration of the food I want to cook. If it's something like Indomie [instant noodles] I can use kerosene. To cook soup, I use (kerosene) stove. But when you talk of beans. Particularly—Or this maize mixed with beans, it takes long before it's ready...I use firewood...We can just enter bush and cut, when you see any dry wood...My landlord is an indigene of this town, so I'll just go to their farm...I go with my children at times...At times, I come back from work around six o'clock and quickly dash to the bush...(I spend) approximately one hour (collecting the fuel)...It can last me for a week” (H20-IT October 2014)

### ***Affordable for acquisition***

Because the vocational activities undertaken by a household serve as an important determinant of the daily activities engaged with over the course of a day — particularly during the working week — it has shown to influence strongly, the sense of availability a household has to an energy carrier; considering how they can integrate with a fuel's source, taking into account their available livelihood resources available such as time, strength, infrastructure and services etc. As the example in the previous paragraph shows, there are other considerations to be had when household decision-makers are choosing to acquire an energy carrier or conversion technology, which influence the other characteristic of access — affordability. After all, monetary factors such as income and price are seen as the foremost influencers of energy decision-making (see Chapter 4).

In the case of energy carriers, it has been observed that when prices are prohibitive, or when income is limited, households prefer to make small-quantity purchases frequently, as opposed to bulk purchases (Fitzgerald et al. 1990). It characterizes the barrier typically associated with a lack of modern energy service affordability — the high upfront cost; which is why much work has been geared towards providing payment packages for modern energy conversion technologies that align with the energy expenditures households are more comfortable with (see Section 3.4). Many households in the communities visited were likewise observed to appreciate flexible purchasing practices, and limited payment packages for their fuel needs in accordance with fluctuations in their availability of funds.

The decision to buy small or buy bulk can also be associated with the conditions of availability. If a household has relatively easy physical access to a fuel's market place and their receipt of income is daily, they may make the decision to make small daily purchases of a fuel in line with the inflow of their monetary base (e.g. H64-IT). If a household has difficult physical access to a fuel, they may choose to make bulk purchases of the resource regardless of their flow of income, and would need to make pre-planned decisions about their fuel spending and use (e.g. H13-IG). For the residents of Itokin, the weekly Sunday market provides an opportunity to purchase kerosene at a price between US\$0.89/l and US\$1.05/l as opposed to the daily offers from community vendors at circa US\$1.27/l. 40 % of the community's interviewed residents cited weekly kerosene purchases of 4 or 5 litres; indicating that weekly spending between US\$3.6 and US\$5.1 was an affordable payment package for meeting their kerosene cooking needs, which can also be part of a stack of cooking energy services. In some cases, this is supplemented with small kerosene purchases during the week from community vendors, as needed (e.g. H58-IT).

While the total expenditure of a household is limited by the depth of their financial resources — since total expenses made cannot exceed the cash and credit available to them — the manner in which they allocate financial capital to their various expenditures tend to

differ. The way participants purchased and made use of gasoline and the private generator respectively, is useful for exploring these differences and what they mean for affordability.

### **Urgency of gasoline-powered private electricity generation**

Though the Itokin, Igbodu, and Ketu communities are all connected to the national grid, and Elujo-Imowo has a community micro-grid, all communities receive the equivalent of a tier-0 level of energy service access from these sources (see Section 6.4). Residents cited only receiving electricity on “three or four” occasions in the year 2014 till October (H64-IT October 2014); others cited not having received electricity from the grid supplier for “three years” (H41-K November 2014). Therefore, some households make use of private gasoline generators to meet their electrical energy service needs. Of the 67 participants included in the study, 10 had *no access* to private electricity generation services at home; 6 of them had access to *shared* electricity generation (this includes the 4 participants from Elujo-Imowo that had access to a tier-0 community micro-grid service, because financing generator operations is undertaken by community contributions); 27 participants *rationed* the use of their home private generator (e.g. two nights in a week); 20 made *daily* use of their generators (typically tier-3 usage in terms of hours of operation, 6 to 8 hours every night; but tier-2 in terms of services used — see Tables 2.2 and 2.3); and the status and/or nature of use for 4 participants was not revealed during interview proceedings.

It can be expected that higher-income households were those able to afford, and thus operate their generators daily, while lower income households would be those typically without ownership of the energy conversion technology. Interestingly, *no access*, *rationed use*, and *daily use* of private electricity generation did not correlate with stated monthly incomes or expenditures. Nor was it explained by community, or the size of a household, or marital status. Indeed, two of the households with the highest cited income/expenditure did not own a generator (H19-IT, H17-IT); while three of the households with the lowest cited income/expenditure figures owned and operated their gasoline generators daily (H26-IT, H51-IT, H64-IT). However, two things were notable. Firstly, none of the participants that cited daily use of their generator practice crop or seasonal vegetable farming on land owned or rented. The significance of this insight is discussed in Section 7.2.2, as this was found to be particularly influenced by the secondary capabilities households *desired* to fulfil by the conversion technology’s *use*. The second point is that a decision-maker’s perception of affordability — or their willingness to allocate financial resources to the purchase of a service/good — is affected by the priority (urgency) it holds relative to other expenditures; and this import given can be subject to change.

Consider this example regarding the lifestyle and expenditure practices of a farmer living in Elujo-Imowo (H7-EI). He is the head of a household of 10 persons that include his wife,

children and mother. His appreciation of electricity and the energy services it facilitates is clear, as he states: “it’s the (grid) electricity that is the best. You know, because we can’t see grid electricity at the moment, we have to use generator. If there was grid electricity from morning till night, then we can charge our phone and it does it faster than the generator. We can’t have the generator from morning till night. If there was grid electricity, we can use other things like the electric cooker. If grid electricity was around—We would like grid electricity more than all these other things...it will encourage vocational activities to spring up. That’s what we need the national grid for” (H7-EI September 2013). Yet, in his home, private electricity generation is rationed.

Though he has access to the community generator that provides 3 hours (7pm till 10pm) of electricity twice a week to households, and for water pumping, he supplements this with private generation of his own; operated sparingly from 7pm till 11pm, on the days he decides to make use of it. The main energy services operated within his home when electricity is available are the charging of mobile phones, his wife’s freezer — which she uses to cool beverages with the aim of sales — and lighting both inside and outside their home. Outdoor electric lighting is particularly useful to them because their house is small in size; necessitating that many activities, aside from television-watching, are most suitable outside. These include attempted sales of beverages and other food items by his wife and mother respectively, as well as an area for his children to do their school homework. His children often go with their mother to collect fuelwood after school; a process he says can take up to three hours of their time in total, and takes place every two or three days. Thus, it is typically after dark when they get home before they get an opportunity for dinner and time to do their homework; and the illumination of their secondary lighting source, used when there is no electricity — the kerosene lantern — is particularly poor for reading and writing, it mainly aids dinner preparation and sales. He highlights that he makes use of two phone batteries because he does not have daily access to electricity. During discussions on how he considers the decision to operate his generator or not vis-à-vis his income, he explains:

“I produce cassava, corn, melon, tomatoes, pepper, okra, and coconut. They all mature at different times in the year so I always have a product that I am selling. When a produce is selling, it can take about one month to complete its selling, but this changes depending on the product and how they mature. On average we will sell every three to five days. Three for tomatoes, corn will be five day selling...If you have 1000 naira [2013 US\$6.4] in your pocket, you can afford to say you want to buy 500 naira [2013 US\$3.2] petrol and put on the generator, because you still have to give the children 500 naira for school tomorrow. If you only have 500 naira, then you can’t then say let’s buy petrol.” (H7-EI November 2013)

In the subtropical climate of the coastal city of Lagos, where annual temperatures rarely fall below 24 °C and humidity is high (NBS 2012, World Bank 2018*a*), smallholder farmers, lacking access to adequate storage facilities, must aim to take their highly perishable products to market as soon as possible following the harvest. Not only do these circumstances deny them the opportunity for market selection, but they must contend with high levels of loss (product spoilage), and undertake the back and forth process described by the participant of picking and marketing, which limits the productivity of their operations. Following this backdrop that leads to uncertainty in the volume of possible sales, the size of his income from trips to the market is subject to variation. From his simple example shedding light on the nature of his behaviour, it is clear that ensuring his children can access the products and services they need on a school day, is a more *urgent* secondary capability than those that can be achieved by fuelling and operating his gasoline generator for electricity services. Between the above two expenditures, on a day when he has ₦1000 (2013 US\$6.4) available to allocate to both, he divides the financial capital between the two. However, on a day when there is only ₦500 available in consideration of those two expenditures, he allocates it to his children's school day, and foregoes gasoline purchases. An awareness of these priorities and funding limitations forces him to ration the use of his generator, such that it is not used every day; and when used, is operated for only 4 hours. Therefore, his threshold spending on school funding for his children is higher than gasoline purchases.

On the other hand, it was observed that for some households, the *urgency* of energy services made possible by operating the private generator are such that the allocation of financial capital to gasoline was important despite limited financial capital. It is worth remembering that participant H7-EI's stated main use of his generator was for charging his mobile phone (for which he had two batteries, negating the need for daily charging), and limited use of refrigeration services (since the demand for beverages in the small town of Elujo-Imowo is considerably lower than other communities that have populations high enough to justify the presence of a central marketplace). Similarly, participant H15-IG spoke of her family's decision to make use of private generation services at home for mobile phone charging only:

“Then as for gen [generator], when—we are not lighting [operating] our gen everyday...So sometimes when we see say the battery and the handset done run down we have to (turn) on our gen, then we go charge our handset, everything will be full, then we go off the gen...Yes, yes (we only ever turn on the generator when we want to charge our mobile phone)...No, no (not for anything else nor at night time generally)” (H15-IG September 2013)

Such was her view on the scarcity of her family's funds that she claimed it to be the main

barrier behind the non-purchase of other appliances that her husband may be more inclined to obtain, such as a television, which will also require greater fuel expenditure, stating: “I’m the one that tells him it’s not time”. She also cited home expenditure levels among the lowest of all participants (2013 US\$60–90 per month). However, her behaviour towards the energy service that facilitates her vocational activity, logging, speaks of a very different attitude towards gasoline affordability. She and her husband undertake logging activities themselves on rented land with the use of a gasoline-powered chainsaw; the produce of which, they sell to customers coming from mainland Lagos or to demand based locally in Epe. Speaking about their purchase of gasoline, she states:

“Ah petrol, I always buy petrol every time, because of the sawing work that I do...I use it for the machine, for my operator inside the bush...Sometimes in a week I always buy—like this 30 litre, three (of them)...That fuel only [alone] is 9,000 (naira) [2013 US\$57.3] a week...this is just for a commercial aspect (I do not class it with home expenditure)” (H15-IG September 2013)

The build-up of their livelihood’s financial capital is directly related to their vocational operations and the efficiency of this work; and the chainsaw is a critical element of their operations’ productivity. Therefore, although their behaviour and her statements indicated gasoline consumption to be of very limited affordability for home-consumption, this was due to relative *indifference* towards the secondary capabilities that home-electricity consumption would enable. Whereas, the secondary capability that facilitates income generation has greater *urgency* and receives a different perception of affordability, or willingness to pay; a different sense of service being financially accessible. They spent US\$57.3 a week on gasoline; and barely use 5 % of the fuel for their private generator. Indeed, it is fair to deduce that the gasoline purchases made for logging were considered by her and her husband, to be investment-spending as opposed to consumption-spending; the latter of which, would be the case for home-electricity operations.

Another family that behaved in a similar manner, is the family of participant H40-IT; where there was a clear difference between the use of the private generator they had situated at their food service shop and the private generator they had at home. The interviewee himself is a logger on rented land and a fisherman, but his wife manages their shop, from which she provides eatery services. Every day in the late afternoon he buys 5 litres of gasoline before joining his wife at the shop, where they remain till 9 or 10pm, before closing to go home. To facilitate service provision after dark, they begin operating their generator from 7.30pm in the evening till close. At that time electricity is predominantly used for lighting and refrigeration services, but also for space cooling upon request, to ensure customer comfort. But at home, they only make use of their generator on Saturdays and Sundays, and

sometimes not at all. During the week, he says they “don’t put it on because of money”. And at the time of the interview, he explained “for about two weeks now, I have never put it on” (H40-IT October 2014). Despite being conscious of their financial resources as regards to generator operations, they are prepared to overlook it when it aids the build-up of their financial capital. But when it does not — as in the case of home-consumption — they consider it unaffordable. The above dynamics, denoting the difference in fuel purchase patterns for the operation of private electricity generation between activities at the home and for income generation due to differences in urgency were also observed to be the case for participant H46-IT; who purchased 10 litres of gasoline daily, predominantly for use at his fish pond. Whereas at home, electricity is privately generated only two days in a week.

### **Urgency of other (energy) services**

Different household perceptions of affordability were evident not just in the behaviours observed with private electricity generation, but also with other services; both energy and non-energy. Earlier (in discussions under the ‘Available for acquisition’ subheading), it was noted how participant H26-IT purchased fuelwood from vendors at the Itokin market centre; where she also bases her stall for providing food service. She is one of two participants interviewed that cited monetary exchange in the acquisition of the fuelwood resource.<sup>8</sup> She cites spending approximately US\$3.9 (2014 exchange rate) daily on fuelwood in addition to circa US\$2.2 on kerosene every day. She uses both fuels daily due to the demands on the taste of local cuisines, and the operational characteristics of both energy services in preparing certain foods. Since fuelwood is freely available in surrounding regions, it is a wonder why she chooses to spend as much as US\$27 per week on the fuel. During earlier discussions (under the ‘Available for acquisition’ subheading), it was observed how non-farmers found it expedient to cease fuelwood use because its gathering required more human capital than the participant could spare due to the nature of their daily activities. Though participant H26-IT is in the same group of participants (non-farmer) she chooses not to cease fuelwood use, but to acquire it from the source that did not require trading off her time-resource in its gathering and collection.

What is witnessed with participant H26-IT is a decision to trade-off financial resources instead of human resources to the benefit of livelihood sustenance. In her case, the consumption of fuelwood and kerosene for cooking services is not simply for home-use, but is at the core of her income-generating activity. As testified by her, she cooks “all throughout the day” (H26-IT October 2014). Therefore, not only does she choose to maximise her income by cooking as many meals as demanded by her customers in a day — meaning her

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<sup>8</sup>Participant H6-IG’s family, as discussed earlier, paid third parties to gather and deliver fuelwood for their use, since his daily activities made manual fuelwood collection costly to him. But having higher income compared to most households included in the study, he had the financial resources to be able to pay for fuel delivery service.

time is tied up in that activity and will be inefficiently spent collecting fuelwood — she also requires large amounts of the resource to fulfil her work. Thus, though the fuelwood and kerosene purchased and cooked with, will be used for home-consumption, cooking has an added level of urgency because it is the basis of her monetary generation (secondary capability of food preparation), and by extension so are the energy carriers and conversion technologies involved in the process. In this case, kerosene and fuelwood purchased cannot be considered liabilities on her monetary capital, but rather investments through which her monetary capital is grown. On the other hand — by her calculations, whether accurate or not — time spent away from her stall gathering freely collected fuelwood would be a liability, as much time will be taken away from cooking meals to be sold. This incompatibility of time spent gathering fuelwood with the daily operations of those trading at the market was also stressed by participant H35-IT, who stated that “there are people there that are using firewood but because of my market, I can’t use firewood, because of time” (H35-IT November 2014).

In another example that picks on the urgency of a secondary capability unrelated to energy consumption, we can see how locals are prepared to stretch their perception of affordability despite limited financial resources, because the capability is particularly crucial to their livelihood. As discussed earlier, participant H33-IG is a farmer, who with her husband moved from an urban town in Delta state to a rented home in the Igbodu community. They migrated in 1984 for work promised in a nearby community, but when preferential employment was given to indigenes of the host community, they began to engage in smallholder farming operations on rented land in the Igbodu community; where they have resided ever since, living in rented accommodation.

In recent times her husband works, as she put it, a “small job, as security (guard)” (H33-IG November 2014), and she undertakes most of the farming activities on her own. Activities such as weeding, harvesting, and manual processing of cassava (to produce garri, and to produce another local staple — fufu (cassava flour)) she undertakes herself; hiring labourers only for planting and the crushing activities during flour processing. Given the limitations of her labour capabilities, limitations are also placed on the size of her plot used in her farming operations. Upon selling the fufu produced from her farming and processing operations, she estimates an income of circa US\$25.6 (2014 exchange rate) a month, which contributes to an approximate household expenditure burden of US\$64 per month. On a day spent at the farm, she wakes up at 6.30am to ensure morning cooking for her house of five persons is concluded by 7.30am (food which may also serve lunch demand). By 10am she is at the farm, and comes back at midday; strength permitting she may go back to the farm in the late afternoon. As needed she fits in fuelwood collection, with journeys on foot to her source; which is relatively “far” (H33-IG November 2014). On a day spent frying



to produce garri, she spends 12 hours undertaking the activity between 8am and 8pm; an activity she says is slowly damaging her eyesight. Due to the limitations of their financial resources, she and her husband do not own a private gasoline generator; despite not having received grid electricity to their rented home for almost 2 years. Indeed, they do not own a rechargeable lantern and only make use of the poorly illuminating and hazardous kerosene lantern for all their night-time operations at home.

The above description of her livelihood has been presented to illustrate the lengths she goes to minimise her costs — by forsaking useful services, and selecting traditional energy services over modern energy services when the option is available — as she seeks to meet different aspects of her household’s livelihood, because their financial resources are limited. However, there is one service she spoke of during the interview, where it was observed she was prepared to adjust her affordability threshold in order to maintain the use of the service — their rent.

“Now we are paying 1500 (naira) [2014 US\$9.5]...a month (for rent)...Before, 500 (naira) [2014 US\$3.2]...when people have been rushing to come (to Epe communities) and then they raise the price...since last year (we started paying 1500 naira).” (H33-IG November 2014)

Despite seeing a threefold increase in the cost of housing in her community, the urgency of her tenancy is such that they must accommodate these changes, and likely make budget adjustments to other areas of their expenditure. Not only are her rental payments important due to the necessity of a home for her family that meets numerous basic and secondary capabilities, but it is urgent because there is little room for manoeuvre or access to alternatives in the face of price changes. In the case of her energy services, either the service was not urgent (those exclusive to private electricity generation) or there were traditional alternatives to modern energy (kerosene lantern and fuelwood stove) that allowed her to maintain a low affordability threshold on modern energy services. However, in the case of housing there is a lack of options because accommodation for rent does not get cheaper than the fee she currently pays.<sup>9</sup>

### **Fuel–technology options for energy services**

The significance of fuel–technology options becomes clear when considering the other domestic energy services that are urgent in a rural setting. Lighting and cooking are particularly urgent to the livelihoods of all people, and the presence of options (both traditional and modern) makes household decision–making less predictable as they seek to maximise the reach of their livelihood resources; which sometimes require energy impoverished choices.

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<sup>9</sup>Those renting a *single room* in Itokin (H46-IT, H64-IT) have the same rental fee she and her family have for the use of two rooms in Igbodu.

With the previous example regarding participant H33-IG and her home rent; the lack of options necessitates selection of the service on offer and making adjustments in the allocation of livelihood resources. Therefore, it can be argued that any urgent secondary capability that is limited to modern fuel-technology operation will require the same treatment; and thus, necessary allocation of resources (financial or otherwise) to the acquisition of the energy carrier and conversion technology, and perhaps lead to transformation of the household's relationship with energy. However, while the use of the modern energy service in such a case can be considered necessary, the resulting relationship between the individual/household and the service can still take many forms; which may hinder its ability to transform the long-term energy decisions and behaviours of the user. Looking at the practices of mobile phone charging in the communities visited is useful for observing this point.

As mentioned in Chapter 6, mobile phones have had relatively high penetration in Epe, just as they have had in the state and country at large. For the residents, mobile phones have become important facilitators of a range of activities such as; income generating activities in client-customer communication, sourcing transportation services to access markets as a supplier (H7-EI, H13-IG) and as a consumer (H11-EI, H14-IG), liaising with family members over remittances (H1-O), and indeed, for makeshift lighting services (H39-IT, H20-IT, H21-IT, H25-IT). Therefore, access to functioning mobile phone batteries have become an urgent demand, and by extension, the electric power that is exclusive to recharging them. The nature of social relations (social capital) and services offered in the communities were such that households can manage to not operate or own a private electricity generator and still maintain acceptable access to electricity for recharging their mobile phone batteries, due to a range of other options on offer; options that desirably have availability and affordability requirements that are of much less drain on the most limited livelihood capitals of a household (such as the human and financial capitals) than buying and regularly fuelling a gasoline generator.

These alternative options include; the use of a neighbour or relative's privately generated electricity, or the payment of US\$0.3/0.6 for battery recharging (specific to Itokin only). Six of the ten participants that had no access to private electricity generation talked about accessing electricity for recharging their mobile phone and rechargeable lanterns by means of one of the above options. Other participants that rationed the use of their private generators also accessed electricity for mobile phone and lantern charging by these means. During cooperation between neighbours, electricity is both available and affordable because the energy service is located next door and is available for free. For those that pay to charge their batteries, there is a clear benefit in paying no more than US\$0.6, which can provide 24 hours of lantern use (H39-IT), than paying US\$3.2 for gasoline over a similar length of time, even if it facilitates the use of more electrical services; because these extra services are

considered non-urgent by the household.

Therefore, with various fuel–technology options available for acquisition to fulfil an energy service, households can satisfy urgent secondary capabilities while minimising the trade-off of livelihood capitals that are most limited; such as their financial capital. But in the absence of options, the threshold affordability for fuels and technologies that serve urgent secondary capabilities is not as fixed as it may otherwise seem. The irony of this observation is that as options in a market become limited and demand for a particular good/service increases, prices for the good/service will also increase. But as we have seen, when the demand to be met by such a service is urgent, the more locals have no choice but to acquire the increasingly costly good/service. This scenario can lead to other compromises on their livelihood capitals that can be undesirable for livelihood sustainability and welfare. Therefore, households having no choice but to acquire modern fuel–technology combinations to meet their energy services is good because they must forsake traditional energy services in such a case; but households having options for engagement is also good, because they can have flexibility in the allocation of their livelihood resources for acquiring the fuels and technologies used to meet demanded services. Important then, for household access, in terms of acquisition, is the presence of a range of *modern* energy services, that differ in characteristics for social interaction according to physical location, source type, prices, and the urgency of activities to be fulfilled; such that households with differing livelihoods — and thus different ways in which they organise their daily life and resources available to them — will be able to access (avail and afford) one or more of the modern energy services on offer.

### **7.2.2 The decision to make use of an energy service**

The previous section discussed the insights associated with one area of energy service decision-making; the decision to acquire the fuel and/or technology, and the manner in which it is acquired. This is the starting point of the energy–household interaction, and the interactions that follow concern the use of the energy service, and any waste management required once consumption is complete. Decision-making with regards to the different interactions are not independent of one another; as the previous section showed, the nature of acquisition will be influenced by plans for consumption (e.g. limited gasoline purchases (acquisition) in accordance with limited operation (use) of electronic appliances) and vice versa (e.g. when a decision against private generator purchase (acquisition) leads to third-party electricity consumption (use) for the urgent energy demand of mobile phone charging). The usefulness of distinguishing between these two modes of household–energy interaction, is that acquisition looks primarily at the influence of the practicality of accessing the fuel and/or technology in the face of limited livelihood resources and particular household or-

ganisation of daily life — where the benefits of use can serve to influence the threshold of access relative to resources available for livelihood sustenance. Whereas in the case of use, examination looks at factors that influence decisions primarily related to fuel–technology operation for energy service consumption.

The specific focus of this section is on insights obtained pertaining to the decision to *make use* of — that is, to consume — an energy service, as opposed to decisions governing the *nature of use*. Aspects of the latter will feature in discussions had in Section 7.3. An investigation of the role of required waste management influencing energy service decision-making was not pursued during fieldwork because for many of the services used by households in this region, there remained limited waste to manage after use.<sup>10</sup> For services that produced notable waste, such as fuelwood and charcoal cooking, the practice of waste dispersal in the surrounding regions of what are unregulated environments, gives the interaction limited room for gleaning insights.

When considering the process of consuming energy to ultimately fulfil a basic capability, the acceptance of that process by a household will be greatly influenced by the technical performance of the fuel–technology combination. With cooking for example, the social interaction with the technical performance of the fuel–technology combination will be evidenced in aspects such as the quality of the food prepared, the length of time it takes to prepare food, the ease of the cooking process, and others (Pundo & Fraser 2006). How these performance attributes are socially interpreted is influenced greatly by the role of *preferences*. Preferences are developed by society-wide attributes, such as culture, but they are also influenced by person-specific attributes including historical experiences, a household's environment, and the individual capabilities of a person (Kowsari & Zerriffi 2011, van der Kroon et al. 2014).

Given the influence of person-specific attributes, the perception of fuel–technology performance can scarcely be explained by the socio-economic characteristics of a population, and this was no different for the locals interviewed in this work. During focus group conversations at the beginning of field work, the first signs of variance between locals of the same community emerged; as residents disagreed between the quality of food prepared between the kerosene stove and the fuelwood stove (Elujo-Imowo residents 2013, focus group conversations, September). As the interviews progressed, there were conflicting statements on the speed of use between the kerosene and fuelwood stoves; likely because of differences in the technical capabilities of conversion technologies used across households, but perhaps also due to differences in user skills. Some residents found the preparation process for fuelwood too stressful (e.g. H52-IT, H55-IT), others did not want to put up with the smoke produced (H36-IT), while others were unfazed by it (H11-IT). A skilled charcoal producer insisted

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<sup>10</sup>The use of the term 'waste' here does not refer to by-products during consumption, such as emissions, but refers to left-over waste at the end of use. For services such as the kerosene stove, waste management required did not venture beyond stove cleaning and kerosene bottle disposal.

that his ability to select and setup fuelwood for efficient burning means that there is limited smoke emissions during his family's use of fuelwood (H13-IG).

For other energy carriers, such as electricity, and the ownership and use of a private generator, it was observed that there may have been a generational influence on the decision to engage with the private electricity source. Nine out of the ten interviewees that did not own a generator had their age noted; and of these, seven were above the age of 40. Whereas, of the fifteen interviewees that disclosed age out of the nineteen that did not restrain their private generator use, thirteen were found to be below the age of 40. This observation suggests there is a reason the younger generation find it necessary to make use of electricity services, whereas the older generation can do without. In conversation, there was widespread acknowledgement of the usefulness and need for electricity services, but in practice this generational division was demonstrated. A closer look at the lives of the participants reveals that the decision for regular use of private electricity, and indeed other modern and transitional energy services, resulted from prior experiences of exposure leading to increased urgency of the energy services facilitated by the energy carrier. This is discussed further under the subheadings that follow.

### ***The influence of a household's historical context***

Some of the energy service decision-making frameworks discussed in Chapter 4 highlight the role of *experiences* as one of many factors contributing to the behaviours of persons and households (see Kowsari & Zerriffi 2011, for example). Here, the importance of experiences as an enabler — or disabler — of consistent reliance on an energy service or fuel-technology combination amidst difficult access, and/or in the presence of competing alternatives is highlighted. One key shaper of the experiences of an individual in Lagos state and the exposure they have to services and products, is the region of the state in which they reside. Urban — and to a lesser extent peri-urban — life is particularly different to the life experienced by members in the rural communities explored. Itokin is the closest of the five communities to having some of the services and lifestyles commonly found in more densely populated and frequented regions, but it still falls short of the environment created in urban areas and the impact they can have on a person's predispositions.

### **Experiences with electricity and household electrical appliances**

Participants that either commuted from urban or peri-urban Lagos to trade in Itokin, or those that split their time between metropolitan Lagos and rural Lagos spoke of service access at their urban homes very different to the permanent rural dwellers. One lady spoke of not needing to buy gasoline for two months, because though electricity supply in her peri-urban community was erratic, the relative frequency of supply meant she and her family could get by with backup lanterns etc., and not have to turn on their private generator

(H66-IT). Another man explained how typical outage periods within his urban commune rarely exceed 24 hours in duration (H27-IT). Amidst greater marketing of a wider array of goods and services, these areas have greater access to modern and transitional fuels and technologies, and thus greater household use; and provide more difficult (or expensive, in terms of livelihood capitals/resources) access to traditional fuels such as fuelwood. Exposed to a wider range of energy services, households in urban regions become more accustomed to their provision. This familiarization remains, even when they relocate to a rural area.

The testimony of participants H15-IG, H14-IG, H17-IT, H33-IG, and H19-IT, who have all resided in their respective communities throughout their lives suggested that electricity in the home, and some of the exclusive services it provides besides mobile phone charging (e.g. television and space cooling services), were not urgent demands:

“No (we do not use our generator for television services)...Don’t use a fan...you know the children in the local area here, immediately you turn on the gen [generator], you turn on the tv, for them to go and carry their book [homework] will be their problem...So let them face their book” (H15-IG September 2013)

“At night time, when we have finished eating, we will pray, everyone just before we sleep. That God should watch over us as we sleep. Sometimes if there is light [electricity], we will watch television. If there is no light, we and the children will sit down and play and chat. And in the morning we all come together and pray as well” (H14-IG September 2013)

“(when there is no grid electricity) there is nothing I will do. I accept that. I don’t use fan. And there is no alternative. When there is no light [grid electricity]. I don’t use anything” (H17-IT October 2014)

“we have (electrical appliances, such as a fan, in our house) but, no light [electricity] to use it” (H33-IG November 2014)

“I have (a petrol generator) before but it is not functioning any longer. Since last year, I have not been using generator...(I have a) television, radio, fan, bulb, and charging of phone...They are intact (but) because there is no light [grid electricity] and I don’t use gen [generator], I just abandon them there” (H19-IT October 2014)

All these were passive in their consumption of privately generated electricity or did not consume it at all. On the contrary, the testimony of participants H41-K, H32-IT, H30-IT, H65-K, H63-IT, and H64-IT, all of whom have spent notable periods of their lives in metropolitan Lagos or other urban regions of Nigeria before migrating (or returning) to rural Lagos, presented very different viewpoints on the urgency of television and/or space cooling services:

“Yes (we turn on the generator from night till morning)...Yes (every day)...No we are not turning it on (in the daytime) unless if we have a certain match that we want to watch...Like Nigerian match...We will on it...Yes (I like football)...I watch Nigeria but I love Euro country than Nigeria...Barcelona (is the team that I like)” (H41-K November 2014)

“My fan (is very crucial to me, it is very important)...I am always after my fan...I don’t like watching television, but my fan and the fridge...they are very important to me” (H32-IT October 2014)

“I put it [generator] on when my children are at home. Often when they are at home, because of heat...when the heat is too much (I leave the generator and fan on till day break)...at times when rain falls, there is no—the heat will not be (that much, so I can turn it off)...Yes (the main reason I leave my generator on for any amount of time is based on how long I want to use my fan)” (H30-IT October 2014)

“(I turn on my generator at 9pm) Because of the heat. Then I would listen to the news and do some other things...Exactly (when my generator comes on at nine, my fan goes on, my TV goes on)” (H65-K November 2014)

“There has been no NEPA light [grid electricity], so I use generator a lot...petrol (generator) I use it mainly to power fan...I use it for lighting bulbs and power the fan...and television...and to charge my phone...I do (use the generator during the daytime) sometimes, if I’m at home...for fan...because I am somebody that used to [often] sweats a lot. I use them to cool myself” (H63-IT October 2014)

“(I have a) TV and radio and fan...Two fans...ceiling fan and standing fan...Yes (I use them at the same time)...(when my generator has a problem I fix it) Immediately...The reason why (I sometimes go and bathe in the river) is when I’m feeling heat, I will now go and bathe in the river...when I’m outside here [in the community centre, away from home]...and when I’m feeling heat...Yes (I will just decide to go and bathe in the river)” (H64-IT October 2014)

In contrast to the first group, who presented apathetic behaviours towards the television and space cooling services electricity provides, the second group presented these services to be very urgent to their livelihoods. As observed earlier with gasoline acquisition patterns, these differences in behaviour were not explained by stated incomes. The difference in urgency can be explained thus: for the former group, a lifetime absent regular television and space cooling services means those residents are not dependent on them for the sustainability of their lives. Though they may consider the services valuable and desirable, they are an added

benefit, almost luxury items, that do not form the basis of their daily sustenance. Whereas for the latter group — who have spent notable time in regions where these services and their support systems have greater accessibility, and therefore more consistency of use, leading to a dependence on the secondary capabilities these services provide — there is a need to operate these services as a means of sustaining livelihoods.

Using Figure 4.8 — that depicts the relationship between energy, services and outcomes — the difference in the two groups can be explained for the space cooling service. The consumption of electricity (energy carrier/secondary fuel) to operate a fan (energy conversion technology) for cooling a space (energy service), is to aid heat transfer from the body to the surrounding air and lower body temperature (secondary capability), leading to comfort (basic capability); or in the case of air-conditioning under more extreme conditions, health benefits (basic capability).

Consider the basic capability of (bodily) comfort for the purpose of explanation. Bodily comfort is a basic need that all humans seek whether consciously or subconsciously (Kolcaba 1994, 2001). The body's response to hot surroundings varies across people; dependent on conditions such as health and age, and can affect cooling requirements (Blatteis 2012).

Nevertheless, the thresholds of bodily comfort will vary across people even when their physical states are similar (de Dear & Brager 1998). Some people require more layers of clothing at lower temperatures to feel comfortable, and some people require evaporation of sweat at a faster rate, or greater heat transfer, at higher temperatures to feel comfortable. The difference is in the level of physical tolerance: the mind's acceptance that the current physical situation is sustainable (de Dear & Brager 1998). Physical tolerance and threshold levels are built from experience over time and can be formed of repetition, but can also be subject to change (Knez & Thorsson 2006, Nikolopoulou et al. 2001). For the group that have been lifelong residents of rural Lagos, amidst very low access to electricity and its associated services, the threshold and tolerance levels for bodily comfort take place at higher body temperatures than those that had spent time in urban areas and were more accustomed to the use of fans. Therefore, there is a difference in the secondary capability required for each group to achieve the basic capability of bodily comfort, which translates through to the urgency of demand for associated energy services, and the fuels and technologies required to operate them.

Now the focus should not be on characterising between life in metropolitan Lagos vis-à-vis life in rural Lagos, because this division only represents relative difference in the presence of factors that lead to households being accustomed to modern energy services. A person or family can spend a notable period of time in metropolitan Lagos, but the context behind their time spent there may not lead to an urgency in the use of services provided by electrical appliances. The same will be true for a lifelong rural dweller, whose circumstances led to the



urgency of television and/or space cooling services. Participant H21-IT, who lives in Itokin but is an indigene of the Ejirin community, south of Ketu (see Figure 6.5) — which has greater trade activity — describes the urgency of his television and space cooling services thus:

“If I feel heat, I will (turn) on generator...If I feel heat, because heat is my problem, I used to [often] sweat...I’m using it because of heat...whenever I’m at home, especially at night...I don’t use more than light and fan...I have television but I don’t use it...I have (a radio) but I don’t use it...Just only my wife and children that use it (at my in-law’s house)...So my video and my television are not with me...In the olden days [in the past] I don’t experience all these things [television] (so I don’t need them)” (H21-IT October 2014)

The Ejirin community is a trade hub, given the suitability of its location by the Lagos lagoon connecting remote communities, and its road route north to Omu in Ogun state. As a result, there is greater use of modern and transitional energy services than is found in some of the more primitive communities included in this research. However, such was this participant’s past life in Ejirin that he did not get accustomed to television services, but did for the use of a fan. The younger generation in particular, are likely to become accustomed to recent developments in their community, such as the supply of entertainment services now on offer in the Itokin community. Participant H20-IT, a lifelong Itokin resident, aged 35, speaks of access to television services either at home or at the market centre as urgent in order for him to watch football and the news. Television services are also used at weekends in the home of participant H54-IT to satisfy the demand of his children. Other Itokin residents, participants H47-IT and H53-IT also spoke of the importance of television services in their home for watching football. In the less developed communities with more primitive lifestyles, there were no lifelong residents testifying as to the urgency of televisions or fans.

Some Itokin residents, though never having lived in an urban area, grew up in families affluent enough to have always made use of generator services and therefore maintain regular use of satellite television services and fans (H58-IT); or are themselves affluent enough to rely heavily on generator services for the aforementioned services, as well as ironing (H62-IT). Similarly, there are some residents in the communities that have spent time in urban areas, but grew up in a home that did not own and operate a private generator and thus, never became accustomed to its uses (H39-IT).

Though participant H39-IT has possibly experienced more frequent access of grid electricity — when she resided in an urban region of Delta state — than is found in the community she currently resides, and therefore appreciates the benefits of television and/or space cooling services, they did not become urgent due to the absence of regular privately

generated supply. The likelihood is that her current affordability of privately generated electricity services respective of all her livelihood expenses, is not enough to justify its inclusion given the lack of urgency of the services it provides; as is explained towards the end of Section 7.2.1. For some other participants that had previously lived in more developed regions, and were likely accustomed to the use of electrical appliances, the cost barrier to regular engagement with a service they want was cited (H48-IG, H40-IT, H56-K, H43-EI, H11-EI); suggesting that regardless of an energy service being urgent, there may be other services of greater urgency competing for the household's livelihood resources. If the relevant livelihood (financial) capital is limited, the household will be forced to make some sacrifices on services that are urgent. Thus, the urgency of an activity is an important determinant of energy service decision-making, but more important is the availability and affordability of the energy service's components respective of the household's livelihood.

### ***Experiences with other energy services***

The influence of prior experiences and exposure to particular energy carriers and technologies on the urgency of energy services, and thus decision-making, is not limited to electricity use. Participant H58-IT (October 2014) though having lived in Itokin all his life, had “never used” the kerosene lantern, and given the shortcomings of the traditional lighting service, found no reason to begin engaging with it despite relatively easier accessibility. Participant H47-IT (October 2014) with the same historical context, “grew up” only making use of kerosene for cooking, and has continued the practice. The same is true for participant H67-IT (October 2014) who never having used fuelwood, confesses that she is “not used to it” for cooking purposes. Participant H32-IT (October 2014), growing up in Lagos, had never used fuelwood, and does not “know how to use it”, leading to his reliance on the kerosene stove. Participant H48-IG attests that from her time in the urban region of Ogun state, she had never used the kerosene lantern for lighting, only rechargeable lanterns, and she had never used fuelwood for cooking, only the kerosene stove.<sup>11</sup> This exposure to specific energy carriers and conversion technologies make them urgent energy services to the participant, and influences decision-making. It is worth noting, that all those that testify as to never having used fuelwood for cooking were either migrants from urban areas, or indigenes of the Itokin community; the latter of which, as mentioned previously, is more developed than the other selected communities, with more favourable access to transitional and modern energy services and less favourable access to traditional energy services when considering the daily activities of many residents.

From an alternative perspective, participant H26-IT (October 2014), experienced the

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<sup>11</sup> As mentioned in Section 6.4 and illustrated with Table 6.4, due to the hazardous, uncomfortable, unclean, and poor quality process of burning kerosene with a lantern for lighting, it is considered to be of less value than burning kerosene with a stove for cooking. Therefore, many who find it forward-moving to use the kerosene stove, also find it backward-moving to use the kerosene lantern, just as they do the fuelwood stove.

use of both kerosene and fuelwood for cooking “from childhood”, and continues the same practices. Participant H59-K (November 2014), a farmer and lifelong resident of Ketu, stresses that she does not “have money for generator” and has never used it, and nor has she made use of transitional cooking service with a kerosene stove. Her stated monthly expenditure circa US\$192 was not amongst the lowest cited among the participants, and her home of four persons in total is not as high as some of her fellow locals. Nevertheless, for her household there is a lack of exposure to the use of a kerosene stove and generator services; which makes the use of both fuel–technology combinations to be of limited urgency. It allows her to view her finances for these fuels and technologies as not being enough, in consideration of the other fuels, technologies, or (energy) services she considers urgent to sustain her livelihood needs.

Only four interviewees — residents of Ketu, Itokin, Igbodu, and a trader in Itokin residing in a different peri-urban community — of the 67 interviewed engaged in the use of LPG for their cooking services (H50-IG, H66-IT, H65-K, H8-K). Another participant mentioned how his wife makes use of the modern energy service at their home in Abuja, where she resides (H56-K). When previously living in metropolitan Lagos, participant H57-IT made use of the fuel and its conversion technology. All the above participants that currently use or have had some experience with LPG cooking, at some point in their lives resided in an urban area; some of them suggesting that their desire for the energy service can be attributed to their previous experience of it:

“(I use) the gas [LPG] (more than kerosene to cook)...(I use kerosene for) like two days—(while I) refill my gas...I use it [LPG] for like one and half month before I refill it...(I buy) about 6 kg...Exactly (I have always used LPG)...Yeah (since I have been here), even before I arrived (I used LPG)...Yes (when I was younger in metropolitan Lagos)” (H65-K November 2014)

“(I started using LPG) two months (ago)...(I started) because it is faster—than kerosene...(I knew it was faster because) I have used it before...I used it for someone before...Yes (I already knew it was good)” (H50-IG November 2014)

“it’s because I don’t have money. If I have money, I’ll buy gas...I prefer using gas than kerosene because I was used to it when I was staying in Lagos” (H57-IT October 2014)

Opinions about the use of LPG were a part of discussions with a further six participants. Participant H41-K considered the modern energy service beneficial, but felt it was more suitable to the urban experience, where there is difficulty utilising the fuelwood stove. Similarly, participant H2-K speaks of LPG; saying she “likes it”, has “used it before”, and “prefer(s)” it, but adds that it is “expensive and far away”, and cannot be used for certain cooking tasks

(e.g. smoking fish). Participant H64-IT was open to adopting LPG should his funds permit him to do so, but found it important that the resulting user be properly trained in its use to avoid accidents. The warning highlighted by the above participant was reason enough for the other three participants to be opposed to the use of LPG, under the belief that the risk of hazards associated with the fuel rendered it not worth using (H23-K, H21-IT, H16-K). Participant H21-IT puts it like this:

“You know for me, I have seen many experiences about gas cooking, I don’t use gas for cooking, I’m using kerosene...You know there is carelessness either from the wife or children...Because when I was at Ibadan...In those days...I have seen about three houses that was burnt by gas...That’s why I hate gas use in my house” (H21-IT October 2014)

The first three positive opinions about LPG use in the previous paragraph, were spurred by opinions of those that had experienced the benefits of its speed of cooking, cleanliness of use, limited emissions and others. However, experiences and exposure can also hamper acclimatisation when they are negative, as is found with the quoted participant. At the time of fieldwork, there was widespread perception amongst the BOP that the LPG cookstove was the most hazardous form of cooking, which could lead to loss of life (Senior manager–Pan-African integrated energy solutions provider 2013, personal communication, November); prompting key marketing companies to undertake campaigns for awareness raising and training for BOP consumers across the country, including Lagos state, as part of a wider push to activate that market (Senior manager–Pan-African integrated energy solutions provider 2013, personal communication, November). Absent first-hand experience of the cooking energy technology, the emotionally-charged narratives about LPG stoves have gained greater prominence in the minds of community locals; with very few people willing to engage with the service “because people believe that it quickly gets exhausted [uneconomical] and at the end of the day, it can cause a lot of disasters” (H57-IT October 2014).

Limited experiences of LPG are not the only reason for its low-level use in the communities visited. For a fuel that competes directly with fuelwood and the *transitional* energy service kerosene cooking — which is perceived in a positive light — access to LPG in the region is not easy. It requires that the buyer be able to make bulk fuel-purchases, relative to fuel purchases typical or possible from community vendors for kerosene, and be able to frequent locations with petrol stations.<sup>12</sup> Thus, only those with suitable ‘availability’ with the fuel’s source — visiting markets with petrol stations by virtue of their daily activities or to aid the functioning of their vocational activity, or whose home is in close proximity

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<sup>12</sup>The LPG fuel is not sold in the communities included for fieldwork as is found with kerosene; Epe town and Ejirin, which have petrol stations, are the nearest locations to access the fuel for most of the communities. The smallest canister size that can be purchased for LPG is 3 kg at a price circa US\$8, compared with purchases as small as 50 cl at circa US\$0.64 for kerosene.

to market sources — engage with the fuel and its conversion technology. But the relatively higher costs of LPG refuelling, amidst kerosene accessibility, renders it a non-urgent energy system, even for those that have been accustomed to its use. As testified by participant H57-IT in the earlier quote, though his time in urban Lagos made him accustomed to the use of LPG, he cannot consider it affordable in this region because it is too costly; making use of the kerosene stove instead. Even for the few that do make use of LPG, they all practice energy stacking; some even making use of all “three types of cooking” (H66-IT November 2014).

It is possible that this element of exposure and experience extends to local usage of microfinance services, credit facilities, and other consumer financing. Further data is required for a conclusive examination of this theme with this group of participants, but at a quick glance there is a suggestion that access, and the decision to purchase solar lanterns with instalments for a few petit-traders in the Itokin community was encouraged by their existing affiliation with a microfinance provider, who supplied them with the modern energy technology (H26-IT, H45-IT, H40-IT’s wife). In the more primitive communities, where there is less exposure to financial services, there is greater apprehension towards loans and instalment payments, out of fear of future inability to meet obligations (H11-EI, H5-IG). This apprehension can differ from household to household depending on the security of income, but the room available to tailor financing to the different circumstances of consumers will not be explored if perceptions remain unchanged.

From the interview insights, it can be argued that an increasing exposure to modern energy services increases the likelihood of consistently experiencing the service and becoming accustomed to it, and the secondary capabilities it facilitates; thereby increasing the likelihood of deciding to demand the service over the long term. But many of the modern energy services discussed with the participants of this study — including the LPG stove cooking, solar lantern lighting, privately generated electricity for lighting — were accompanied with energy stacking; where the inclusion of modern and/or transitional energy services did not lead to discontinued use of traditional energy services. The next section will explore why energy stacking is the case, and what the interview insights reveal about what can be done to facilitate more complete transitions in household energy services.

### **7.3 The nature of household transitions in rural Lagos**

In Chapter 4, four categories of outcomes from the introduction of new (energy) services were presented based on well-documented experiences in the literature. In the most unsuccessful cases, there may be minimal-to-no uptake of a new energy carrier and/or technology among a set of people or within a market — *no transition* (see Section 3.4). Following on from that are cases where an energy service is initially adopted but is soon out of use; a case that

characterises much of the donor-led initiatives during the 1980s — *unsustainable transition* (see Section 3.2). The outcome that has been typical of recent observations in the field consists of households adopting a newly obtainable energy system and making collective use of their pre-existing and new energy systems — *incomplete transition* (otherwise known as energy stacking). The final outcome is a situation where the energy poor substitute their use of traditional energy services with new (modern) energy services to fulfil their respective energy demands — *sustainable transition*. These outcomes are by no means fixed over the medium to long term, and it is possible that households move across the spectrum of transition-outcomes over time. However, it has been the case that incomplete transitions have been the long-held destinations of recent energy access efforts (see Chapter 4). What can the communities visited reveal about the reasons for this? And what can they reveal about what it takes to move transitions along to the *sustainable* outcome?

According to widely used definitions of energy poverty, there are two key energy services that all persons worldwide require: cooking and lighting (see Chapter 2). This was the case for residents interviewed in this research as *all* participants spoke of having some form of cooking or lighting practice when the topic was discussed. In keeping with observations in the literature, from studies across various contexts, a fair number of households that used some form of transitional or modern energy service to meet the two above needs, did so by stacking them with traditional or other transitional energy services.

36 of the 67 participants (54%) stacked their cooking energy services; with all but three of the 36 including some form of traditional cooking (fuelwood or charcoal) as part of their regular cooking pattern. For the remaining 31 households making use of a singular type of fuel-technology combination for their regular form of cooking, only one household relied exclusively on fuelwood; all others made use of the kerosene stove only. Out of the 30 participants that relied exclusively on the kerosene stove, eight testified using fuelwood cooking during parties and festive seasons or for the occasional smoking of fish, given the bespoke needs of these activities which can currently only be met by fuelwood stoves (load and heating requirements). It is expected that many more of those interviewed that did not specifically mention the above, are also likely to engage in the practice, given cultural practices on foods made for parties and other festivities. Of the 33 interviewees that did not include traditional energy services for regular cooking (3 that stacked transitional and modern cooking energy services; and 30 that relied exclusively on kerosene cooking) eight of these indicated having previously relied on traditional cooking (a sustainable transition). For the other 25, some have only ever made use of kerosene for their cooking — as discussed earlier in Section 7.2.2 — and conversation with others did not provide any confirmation or otherwise on prior difference to their current cooking energy practices (see Table 7.1).

In the case of lighting, close to non-existent grid electricity provision for connected

**Table 7.1:** Breakdown of participant household cooking types

	Energy stack		Single energy system type	
	<i>With traditional<sup>a</sup></i>	<i>Without traditional<sup>b</sup></i>	<i>Traditional<sup>c</sup></i>	<i>Transitional<sup>d</sup></i>
Participants	33	3	1	30

*Note:* <sup>a</sup>includes the use of traditional fuelwood and/or charcoal cookstoves

<sup>b</sup>consists of at least two of the kerosene, LPG, or electric cookstoves

<sup>c</sup>fuelwood stove only

<sup>d</sup>kerosene stove only

communities and widespread use of generators for limited hours — even if daily — in all communities, meant that energy stacking, at least across grid/gasoline-powered generation of electricity to light bulbs and stand-alone lighting devices, was a feature of all households. Even for the ten households that did not make use of a generator, light bulbs were owned for the rare instance grid electricity was made available. Discounting the provision of lighting from grid/gasoline-powered generation of electricity, and considering the use of stand-alone systems only, household lighting maintained notable instances of incomplete transitions. 36 of the 67 participants stacked their stand-alone lighting sources; with 31 of them including at least one form of traditional lighting system in their stack (kerosene lantern, locally constructed fragile battery-powered lamp (ojutinepa), candles). Of the five that stacked modern stand-alone lighting systems, three of them stated during the interview process that they have transitioned away from traditional lighting (sustainable transition), and one mentioned only ever having experienced modern stand-alone lighting. 25 of the participants relied on only one type of stand-alone lighting; two of which made use of a particular type of traditional lighting service, five of these confirmed never having made use of traditional lighting, and nine of the 25 confirmed they made a transition away from traditional lighting services (sustainable transition) (see Table 7.2). There was insufficient lighting information obtained for six participants during interview proceedings with them.

**Table 7.2:** Breakdown of participant household stand-alone lighting types

	Energy stack		Single energy system type	
	<i>With traditional<sup>a</sup></i>	<i>Without traditional<sup>b</sup></i>	<i>Traditional<sup>c</sup></i>	<i>Modern<sup>d</sup></i>
Participants	31	5	2	23

*Note:* <sup>a</sup>includes the use of any one of the kerosene lantern, ojutinepa, and candles

<sup>b</sup>consists of at least two of battery-powered torches, rechargeable lantern, solar lantern, or mobile phone torchlight

<sup>c</sup>kerosene lantern only

<sup>d</sup>rechargeable lantern only

As is found with both the cooking and lighting experiences, all households seek to meet

these needs because the secondary capabilities of eating home-cooked food, and being able to see at night time are *urgent* for the sustainability of their family’s livelihood (or lifestyle/way of life). Drawing on the household transition framework postulated in Figure 4.9, we should expect to find experiences with the two respective energy services operating in either the incomplete transition or sustainable transition quadrants; because of the *urgency of their related secondary capabilities*. The observations presented above largely confirm this. For cooking, a combined total of 67 % of the participants either experienced incomplete transition or a sustainable transition to transitional or transitional/modern cooking service. This percentage could be higher since there were households that did not confirm whether having previously made use of traditional cooking before beginning the use of transitional cooking.

However, one household did not make some form of transition from traditional cooking (no transition), and there were a few instances of ‘unsustainable transitions’ to modern energy cooking; the significance of these observations — which the framework does not capture, as it attributes such behaviour to services that serve secondary capabilities that are *not* urgent — are discussed in Section 7.3.2. The section will also touch briefly on the ‘no transition’ experienced with those that have always relied on the *transitional* kerosene cookstove. The insights emerging from the instances of sustainable cooking transition are discussed in Section 7.3.3.

In the case of lighting, even when considering stand-alone lighting only, another combined 67 % experienced incomplete transition or sustainable transition to modern energy services. Again, this number could be higher due to households that did not confirm having previously relied on traditional lighting or not. Nevertheless, four households did not make some form of transition in accordance with the postulated framework (they had ‘no transition’) — two of which, stacked their traditional stand-alone lighting systems; and these are also discussed in Section 7.3.2. Insights from the twelve confirmed sustainable transitions experienced with stand-alone lighting are discussed in Section 7.3.3.

### 7.3.1 Incomplete transition (energy stacking)

According to the household energy transition framework in Figure 4.9, incomplete transitions also emerge because an energy system used to fulfil an urgent secondary capability, is *not* considered urgent to a household; that is, the energy carrier–conversion technology combination are not *needed* for the undertaking of the urgent energy service used to fulfil that secondary capability. For a household to consider an energy system, used for an urgent activity, to be non-urgent, there must be an alternative; since that urgent activity must be fulfilled. As presented in Table 6.3 there are several energy carriers and conversion technologies available to households in the study area for the urgent activities of cooking and lighting. Therefore, even if the energy poor consider the use of modern fuels and technolo-



gies beneficial, their use would not be considered *necessary* to the fulfilment of their urgent activity, *ceteris paribus*. However as seen in Section 7.2.2, a modern energy service can become urgent by virtue of the experiences of a household, influenced by their environment.

The interviews revealed that even as the desire for and access to modern energy services increased, such is the dynamic nature of the cooking and lighting demands that they are unable to account for the entire scope of these household demands due to shortfalls in scope of the energy service supplied and household resources. This can be observed, for example, in the household lighting demand. At sundown visibility is needed for the undertaking of a number of tasks: movement outside; stationary activity outside in kitchens when cooking dinner; indoor activities. The nature of these tasks may differ, for example, based on the nature of human interaction with the task, and therefore the nature of visibility required and thus illumination. Flexible location of illumination or limitations in the size of the lighting device might be needed for viewing tight spaces (H61-K). Differences in the nature of the task may also allow or limit the various ways in which human interaction with the lighting energy technology can be undertaken. A task that requires both hands may make it impractical for the use of a lighting device that must be held.

Stand-alone and networked energy systems address these varied lighting needs in different ways. With networked electricity; street lamps fed by one source of generated electricity, along with light bulbs in relevant locations of the home also fed by one source of generated electricity, are well placed to meet most of the diverse lighting interactions that are considered above. However, in the case of stand-alone lighting devices, such as those largely relied on in the communities, each source (system) of energy is limited in its fulfilment of the various lighting needs a household can have. Firstly, because each lighting system can typically only serve one of the aforementioned household-lighting needs at a time — whereas households require simultaneous sources of light in different locations for different activities — there is a natural need to have numerous stand-alone lighting devices. The average household interviewed owned three stand-alone lighting devices; a number which fluctuated depending on aspects such as the number of rooms in their house and the hours of private electricity generation per day for bulb-lighting. For financially constrained households it can be necessary for at least one of the lighting devices to be of the traditional kind. These households spoke of making use of the risky kerosene lantern in areas where the lighting source requires limited movement, allowing other lanterns that are less prone to accidents — such as the battery-powered lantern — to satisfy lighting demands on the move:

“When we want to sleep we will leave the kerosene lantern (on)...I on those ones [rechargeable torch], maybe when we want to go to backyard...(before bed) we use both (light sources) together. We put on both the hurricane [kerosene]

lamp and use the torchlight because—like the hurricane lamp is meant to be—stationed in one place while the torchlight is for movement...You want to take something inside or use outside” (H45-IT October 2014)

“We are using shade [kerosene hurricane lamp]...inside room...Always in the room...No (it never moves) because we are using it. If we want to cook, we will use torchlight...(the) rechargeable ones. Standing ones...(we put the kerosene one in the room and the rechargeable one in the kitchen) because of the transfer of lantern—from inside (the room) to inside kitchen...I prefer the kerosene (one to be stationary in the room)...Because sometimes in the night, if I want to stroll out—I will take the torchlight—and my son will be inside the room—so that is why I prefer to use the lighter [kerosene lamp] will just be there” (H53-IT October 2014)

Secondly, each stand-alone lighting system will have socio-technical advantages and limitations that can facilitate the suitability of its use for some activities, but hinder it for others. As the quotes above alluded; just as the kerosene lantern is considered impractical for moving around, so it is that torches are practical and necessary for night-time movement, in the absence of street lighting. Other residents behave similarly (H37-IT, H67-IT); and is also a reality for households that choose not to rely on traditional energy services in the stack, but stack they must nonetheless, due to technical characteristics of various stand-alone lighting systems (H60-IT). Given the technical limitations of many solar lanterns, in terms of battery-life after recharge, some of those that have started engaging with the modern energy service — by virtue of an organisation of daily life that has exposed them to the technology and made it more accessible — must still engage with other lighting services to meet the totality of their lighting demand. As mentioned in Section 6.4, rural life begins for many residents before the break of dawn, and so morning-lighting demand is common. Since the solar lantern’s energy is expended during night-time activities, participant H26-IT needs the rechargeable lantern in the morning — which she charges at night when making use of her generator — for her children to sweep her shop before daily trading commences.

The presence or removal of traditional energy services in the household lighting stack is then down to livelihood resources or lifestyles that either facilitate their exclusion or necessitate their inclusion. For example, even for households that utilise electricity daily, there is still a tendency for traditional energy services to be introduced into the stack; in some cases, it becomes the preferred option over the modern option to perform the same function. For participant H13-IG, who incorporates smallholder farming, hunting, and security guard services for CERUD for income generation, his non-rechargeable torch is an important lighting service for his night-time security work, in addition to general night-

time movement. Operating his private generator daily is important to his household, but due to monetary constraints, they only do this for 3 hours every night and therefore need other home-lighting services to illuminate outside their home, their parlour, and bedroom. Given their perceived affordability of other energy sources — with the consideration that they must fuel their generator daily — they have decided to rely on kerosene lanterns for supplementary lighting, as opposed to clean lanterns.

“If I want the power of the generator to work well then I have to turn off some appliances...(I turn off) the bulbs...(we use the generator) at night time, from 7 till 10. And then I will turn it off...Everyday...Everyday...I use it [the generator] for light sometimes, I put it [the bulbs] off so that the television can work well with it [the generator]...No I don't (use the petrol generator at the same time as the kerosene lantern)...when we don't use the generator then we turn on our lamp with kerosene...when we turn on the generator we will not use lamp [kerosene lantern]...(when we turn off the light bulbs so the television can work well) we will use the light from the television to see ourselves...You know petrol, the petrol always costs a lot of money so—(we use) more kerosene than petrol...(we use the petrol generator) everyday but it's for a short time...From 10(pm) we will make our lamp of kerosene...(And we will leave that on) till day break” (H13-IG September 2013)

Earlier in Section 7.2.2 it was mentioned how participant H66-IT, who lives in a peri-urban locale with more frequent supply of grid electricity did not need to rely on private electricity generation much. This was achieved due to a reliance on the kerosene lantern instead. She spoke of how her rechargeable lantern is necessary for outdoor lighting given the absence of street lighting and to go to her ‘backyard’. But indoors, she maintains the traditional kerosene lantern as part of her energy stack to be used during most blackout periods, as opposed to turning on her generator. Her reasoning here is that because their blackout does not last as long as those experienced in the study-communities, her household can do without electricity services for a time and manage with the kerosene lantern for the urgent secondary capability of night-time vision; even if this may mean relying on the kerosene lantern in excess of 6 hours during a blackout, and perhaps as a daily occurrence.<sup>13</sup> When blackouts last longer — to the point where the use of an electricity service becomes urgent — then it seems, is the private generator operated. So therefore, increased grid electricity access, as opposed to displacing the traditional kerosene lantern, rather displaces the private electricity generator.

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<sup>13</sup>As mentioned in Section 6.3.4, the average weekly supply of grid electricity across the country in 2013 was estimated to be 35 hours per week, with blackouts lasting in excess of 12 hours. Though her supply is higher than that of households in the communities visited, it remains very low; therefore necessitating a fair amount of backup lighting.

“I have generator...Ah, no (I do not use it every day) because they have given us light, (in) our side [community], we have light...they are giving us (grid electricity supply) all the time, all the time [frequently]...we don’t have light yesterday but today before I will reach home they would (have given us electricity)...I have (kerosene lanterns) yes...I’m using it if NEPA [grid electricity] takes light [blackout], I use that one...I (even) used that one today since yesterday...we don’t have light since yesterday...No (I didn’t turn on my generator)...Not always (will we turn on the generator)...because we have light [grid electricity] so I don’t (have to turn on generator)...It’s been like two months now (since I turned on the generator)” (H66-IT November 2014)

Therefore, the dynamic nature of the lighting needs of the energy poor is such that incremental stand-alone energy systems provision — whose integrated system of energy transformation provides one channel of (lighting) service output — will likely fall short of meeting the totality of household urgent lighting needs. Even the participant with one of the highest private generator consumption practices still relied on his rechargeable lanterns between the hours of 7pm and 9pm before settling down at home to put on his generator (H65-K). Because modern forms of stand-alone lighting are not the only product in the market, there is no urgency as to their adoption, amidst competition from the more traditional forms. Incomplete transitions are then possible under limited livelihood resources or when organisation of daily life favours traditional accessibility over modern accessibility. Furthermore, if the necessary range/variants of modern technical solutions are not available to meet the dynamic demands, then incomplete transitions persist. Just as traditional lighting systems that can be locally constructed (ojutinepa) in the very remote Oriba community favour their inclusion in the energy stack relative to modern counterparts that must be sourced across the lagoon, so does the absence of a modern cookstove that can smoke fish or can handle the pot size required for party-cooking, ensure the continued widespread reliance on the traditional smoking stove in the cooking energy stack. These cooking outcomes are *urgent* in the socio-cultural context of these communities.

### 7.3.2 No transition and Unsustainable transition

In Section 7.2 the behaviours and perceptions of some participants towards the private electricity generator were presented. Some participants had previously made use of the service before a breakdown in technology triggered discontinuation of use; a typical illustration of an unsustainable transition (H19-IT). Using Figure 4.9, it was postulated that the potential for an unsustainable transition can stem from the use of an energy service to fulfil a secondary capability that was considered non-urgent by the user, even when the fuel and technology used to operate the energy service were necessary for undertaking that service (e.g.

electricity for television services to achieve the secondary capability of telecommunicated information and entertainment). In such a case, when accessibility becomes challenging — either through limited livelihood resources or availability challenges — it is possible for the energy carrier, conversion technology and the energy service they serve, to be discontinued. This is because the operation of that service and the fulfilment of its secondary capability is not crucial to the livelihood of the user. In the case of electricity for television, fan and other electrical appliances, this was the experience of participant H19-IT who was quoted earlier (Section 7.2.2) to have abandoned the use of these appliances once his private generator broke down.

However, these transitions were not only observed in cases where the secondary capability to be fulfilled was *non-urgent*. The Oriba, Igboodu, and Elujo-Imowo communities all have boreholes installed in their communities, but issues such as a faulty generator for water pumping necessitates use of a nearby river to access bathing water, and the purchase of drinking water from community vendors. In the most extreme cases it leads to a sustained reliance on the river source (the case of Oriba, and for lengthy periods of a faulty generator in Igboodu); another example of an unsustainable transition. However, water for bathing or drinking is an important (urgent) secondary capability. According to the framework in Figure 4.9; under these circumstances the potential transition should be for incomplete transition, given the significance of the secondary capability to be achieved and the non-urgency of the mode by which the service of water provision can be accomplished, since there is an alternative that is not foreign to the users. When pumped water services are available intermittently, the response of residents is to juggle between pumped water service and sourcing from the river (evidenced mainly in Elujo-Imowo) — service stacking, which is the expected incomplete transition according to the framework. But when the service supply is hampered, essentially rendering supply-side inaccessibility to the service it becomes an unsustainable transition; though this is against the natural desires of the users. Participant H5-IG's comments illustrate this:

“There is a borehole, but where it is located is far. Sometimes when we get there they'll tell us that there is no petrol to use for the pumping of the water from the borehole. We'll now carry ourselves to the river. We have a river nearby that we use, and we use it for drinking as well...the government erected the borehole, but due to the lack of electricity and—or a fault with the generator, we have to go to the river to fetch water...My wife (gets the water from the borehole)...We have a drum, the two hundred litre one and she'll go back and forth about four times to fill up the drum. It might take her two hours. It should last us about four days...(She carries the water) on her head. Not the drum itself. She uses a

small container to go back and forth...(For the river) that takes a while! To fill up the drum, it could take more than four hours...If there is a good generator, then we will be able to see (borehole) water. Because going to the stream is tasking. But we have to do it. Water is essential” (H5-IG September 2013)

What we see therefore are *access issues* making it possible for unsustainable transitions in situations where the secondary capability is urgent and the urgency of the (energy) system for fulfilling a service is low, given the presence of a relatively reasonable alternative; therefore, extending the unsustainable transition outcome towards the conditions of the incomplete transition segment on Figure 4.9 — that is, the outcome of unsustainable transition when the associated secondary capability is urgent.

As mentioned in Section 7.3, there was one instance of ‘no transition’ away from the traditional fuelwood stove in the case of participant H59-K. Earlier (see Section 7.2.2) it was discussed how she considered private generator services to be unaffordable to her household, and she also stated not having the “money to buy kerosene”, as would be required for daily kerosene stove use. According to the framework set out in Figure 4.9, the urgency of her cooking need combined with the presence of various energy solutions in the market for cooking — making them non-urgent — should also render her transition in the ‘incomplete transition’ segment of the figure. However, her *inaccessibility* of all fuels, save for fuelwood, again sees her ‘no transitions’ outcome extending towards conditions of the incomplete transition segment.

A similar situation is found for the LPG cookstove, where some participants were observed to be opposed to the use of the energy service for reasons based on the safety of use (see Section 7.2.2). But eating home-cooked food is an urgent secondary capability for all households that feed themselves; though the LPG stove is non-urgent for many households given the accessibility and user-acceptance of the kerosene and fuelwood stoves. This suggests the potential transition is again in the upper-left quadrant of the illustration in Figure 4.9, with an incidence of energy stacking; but the aversion to the stove did not lead to this. The observed reality however, was no transition. In other words, the potential users considered the sustainability of their human capital (health) to be incompatible with the operation of the LPG cookstove; akin perhaps, to perceptions of other unsafe traditional energy services such as the kerosene lantern. Similarly, those with relative availability to the stove, but difficult affordability due to the high costs also did not undertake transitions. Therefore, from the above examples we see the influence of *negative perceptions* and *access issues* extending ‘no transition’ outcomes towards energy services with market and social characteristics associated with the incomplete transitions segment of Figure 4.9.

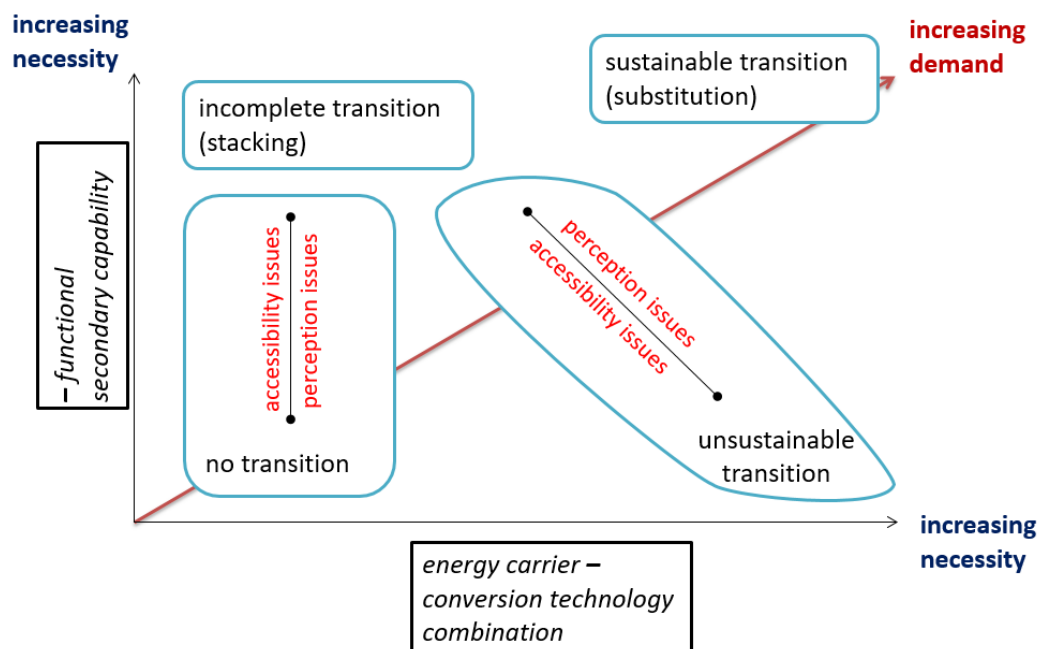
The four instances of ‘no transitions’ to modern stand-alone lighting also find accessibil-

ity issues rendering the conditions expected to lead to incomplete transitions — given that night-time vision is an urgent secondary capability served by multiple accessible lighting systems — achieving outcomes of no transition. For example, participant H15-IG finds the necessary washing of soot from the lamp-body to be the only issue with the kerosene lantern but not enough to serve as a deterrent; having other urgent livelihood needs that must be met before the adoption of a modern lighting system (unaffordability). This also explains why there was no transition from the transitional energy service kerosene cookstove for those who started off with it, because of the influence of accessibility and perception from experience. LPG is not very accessible compared to kerosene, and locals appreciate the kerosene cookstove; giving it a good perception. So, ‘no transition’ is the outcome of a fuel–technology combination that meet an urgent energy service (lighting), crucially, because there is the presence of an alternative that will operate as a sustainable transition or alternative(s) that will operate as a stack of fuels and technologies in an incomplete transition. Thus, even when the energy service to be fulfilled is an *urgent* one, *inaccessibility* and *aversion* to an energy service can lead to both ‘no transition’ or ‘unsustainable transition’ outcomes; so long as there is an alternative which is *accessible* and *liked/tolerated*.

From these insights therefore, the illustration in Figure 4.9 can be altered to depict the influence of *accessibility* and *experience/perception* (with respect to a household’s livelihood sustenance) in extending the operation of unsustainable transitions or no transitions closer to the region of incomplete transitions; where energy solutions that fulfil urgent secondary capabilities of bodily cleanliness, night-time vision and eating food are at risk of not being adopted, or discontinued. This is depicted in Figure 7.1.

These insights on the influence of accessibility and experience/perception on no transitions or unsustainable transitions are obvious, and expected; as households cannot, and will not, make use of what they do not have or find risky/threatening, especially when there are suitable alternatives. But importantly, what these insights also suggest is that if the reverse of the experiences described above could be true for the energy services of the energy poor; where modern energy services were made accessible via consistent market supply and the organisation of household daily lives, and obtained positive experiences/perceptions, while traditional energy services were made inaccessible and/or locals are enlightened to know and appreciate the true ills of these services, then the latter can reach outcomes of ‘no transition’ or ‘unsustainable transition’, regardless of the urgency of their associated secondary capability. The next section will examine how this fits in with the observed instances in the field, of sustainable ‘complete’ transitions to modern or transitional energy services.

**Figure 7.1:** Framework illustrating the effect of accessibility and perception issues on the transition outcomes of energy solutions that serve urgent household needs, in the presence of alternative solutions



Source: Author's depiction

### 7.3.3 Sustainable transition

Throughout discussions had in this chapter, and particularly in Section 7.3.1, it has been shown that no matter how technically impressive and accessible a modern (or transitional) energy service might be, household energy demands and livelihoods are such that if traditional energy services remain accessible, then energy stacking (incomplete transitions) is possible. This was observed for participant behaviours and experiences with LPG and kerosene stoves; and with modern lighting (both bulb and stand-alone lighting systems). According to the framework, it is expected that sustainable transitions likely take place when the secondary capability to be fulfilled by the consumption of an energy service is urgent (see Figures 4.9 and 7.1). The obvious candidates to observe such transitions then, are with cooking and lighting energy services.

At the same time — as shown in Section 7.2.2 — there are new fuel–technology combinations used to fulfil old (and new) energy services (and by extension secondary capabilities) that are (or have become) urgent to the livelihood of a household. This was observed in cases such as mobile phone charging for long–distance communication, the use of space cooling fans for bodily comfort, and also in some occupations that made use of an electrically–powered machine; rendering the energy carrier used to power these energy services — electricity —



to be urgent.

Some represent the generation of a new secondary capability (e.g. instant long-distance communication) that households grew to appreciate; and others represent a new energy service that is serving an existing urgent secondary capability (e.g. electric fan for bodily comfort). Electricity and the respective modern conversion technologies for the above energy services are the only available options in these markets for fulfilling these urgent secondary capabilities, thereby rendering them also urgent (necessary) — thereby achieving a sustainable transition as illustrated in Figures 4.9 and 7.1. On the other hand, electricity remains non-urgent for other urgent demands (cooking and lighting) that can be fulfilled by other traditional and transitional energy carriers. And as observed in the examples of incomplete transitions, many households still rely heavily on these traditional energy services for lighting and cooking, even when electricity has become urgent to them for other new energy services.

Interestingly however, as introduced in Section 7.3, there were eight confirmed instances of a sustainable transition from traditional fuelwood cooking to transitional kerosene cooking amongst households; and twelve confirmed instances of household sustainable transition from traditional kerosene and candle lighting to modern battery-powered/rechargeable lanterns. The testimonies of these participants are discussed below, beginning with cooking.

### ***Sustainable complete cooking transitions***

For a couple of these eight participants there was limited insight as to the drivers of this transition (H34-IT, H36-IT); some participants attributed the change to natural progression with societal development (H19-IT); but others revealed some interesting points. Participant H18-IT spoke of how she made use of two kerosene stoves at the time of fieldwork. When she was younger, living in Ogun state, her family made use of fuelwood cooking services. She highlights that though she prefers the kerosene stove, fuelwood remains beneficial for cooking large meals and for smoking fish, but given that she lives in rented housing in the Itokin community, which has no provision or space for outdoor cooking, she is forced to do without it.

“That was then (that we used fuelwood to cook) but now, nowhere to make fire...Yes (I would use it if I had somewhere to make the fire)...I prefer (kerosene) stove...(But I will use fuelwood) at times when we have these festive (celebrations)...enh [yes] (and to smoke fish)” (H18-IT October 2014)

In her case, her new-found organisation of daily life, which included living in a home that had no facilities by which fuelwood cooking could be undertaken, rendered the traditional energy service inaccessible. Essentially, kerosene became the only cooking energy solution she had access to for her urgent cooking activities, making it necessary — an urgent fuel-technology

combination. This is the same situation facing participant H17-IT that necessitated he discontinue the practice of fuelwood cooking. Before he got married and moved home to rented accommodation he made use of fuelwood.

Earlier in Sections 7.2.1 and 7.2.2 it was discussed how participant H50-IG makes use of the kerosene and LPG stoves respectively. This followed a transition from childhood practices where she made use of the fuelwood stove to cook for her family, at a time when they practised smallholder farming. After having schooled in metropolitan Lagos, with positive experiences with the kerosene and LPG stoves, she has chosen to stack these non-traditional cooking services upon her return to rural Lagos; which she accesses in synergy with the sourcing of the products she sells (she also sells kerosene — see Section 7.2.1). But the nature of her work as a petit-trader gives difficult availability to freely gathered fuelwood. Therefore, we see *access issues* to fuelwood, supported by strong access and experience/perception of kerosene and LPG leading to a sustainable transition away from the traditional energy service.

Though she did not mention it, it is likely this transition away from fuelwood would also have been supported by an appreciation of its negative characteristics. As mentioned in Section 7.2.2, some residents disliked the difficult process of sourcing good quality fuelwood, of arranging the wood and stove for use, the smoke emissions, the unclean impact on pots following use; and others did not mind. For some of those that it did bother, these negative perceptions of the traditional energy service, born of experience, was an important driver behind a sustainable transition away from the solution (H44-IT, H55-IT). Participant H44-IT explains it thus:

“Yes (kerosene is the only type of stove that I have)...That was then [in the past] (that I used fuelwood)...Maybe two years ago (is when I stopped using fuelwood)...(I stopped) because of the stress...The firewood at times, if the stick is not yet dry—the fire will not get burned—that’s why I stopped it...I stopped that one [fuelwood] that is why I buy kerosene stove...(I did not use the kerosene stove at that time) because of the cost (of) kerosene—that’s why I used firewood before—but the stress is too much, that’s why I changed to stove” (H44-IT November 2014)

As her quote rightly points out, these substitution transitions require the availability and affordability of alternatives. Later in the same interview with the above participant — when she was asked what prompted the decision to discontinue fuelwood use, considering that stress associated with the fuel would have long been an issue — she revealed the previously unsustainable transition of kerosene cooking and the role affordability played in the changes.

“Yes (fuelwood has always been stressful)...In the first place, when I was using

firewood—kerosene is too cost [expensive] then—Do you understand? That time we buy per litre at least—is it not 165 or 170 (naira) [price year unknown, but >US\$1.1]...So I now changed to firewood—And [moreover] if I use firewood then, my food...will get (ready) faster than kerosene—But when the kerosene now came down to 125 (naira) [price year unknown]—per litre...That’s why I change...to kerosene...Yes (I was using kerosene first, then went to fuelwood, then now came back to kerosene)...Firewood is faster than kerosene...But it’s stressful” (H44-IT November 2014)

Her quote indicates the individuality of experiences and perceptions in leading to discontinued use of an energy solution; as they relate to aspects of a more personal domain, indicating the influences of attitudes and predispositions (see Chapter 4). The influence on behaviour of the negative social interactions with fuelwood will differ widely from household to household. For participant H44-IT, it was necessary for kerosene to become affordable to her before the discomfort of fuelwood could be acted on. Her experience and perception of fuelwood to be faster than kerosene will have also played its part in her transition decision-making. Under limited resources, experiences and perceptions are more influential in shaping non-use if the energy solution is considered a threat to the sustainability of the person’s and their household’s livelihood; as observed in Section 7.2.2 with the negative reputation of LPG to some households. Absent these livelihood–sustainability threats, different households with different histories, attitudes, livelihood capacities, and surroundings will vary in their response to the pros and cons of fuel–technology engagement; the accessibility to an alternative energy solution takes precedence, and there is greater room for incomplete or unsustainable transitions. Her behaviour towards the formerly higher price of kerosene may have been different if engagement with fuelwood cooking included trade-offs that, in her view, threatened the sustainability of her family’s livelihood.

### ***Sustainable complete lighting transitions***

According to the testimonies of the twelve participants that confirmed a substitution (sustainable complete) transition in stand-alone lighting, there is one overwhelming driver of the decision to discontinue the use of the traditional kerosene-based lighting service — the risk of accidents associated with its use. Eight of them attributed the above reason to their discontinuation of the fuel–technology combination (H8-K, H17-IT, H20-IT, H21-IT, H27-IT, H29-IT, H40-IT, H49-IG); another two participants respectively spoke of the impact it had on their nasal cavity function (H63-IT) and cleanliness of their home (H61-K) as reasons for transitioning away; and for two participants there were no clear reasons given for the change (H19-IT, H28-IT).

This emphasis placed on the risk of accidents by households as a reason for discon-

tinuation is in line with the acknowledgement of Johnson & Bryden (2015) — reviewed in Chapter 3 — that perhaps the salience of hazards that pose risk of physical injury may be a stronger driver of household transition than the effects of indoor air pollution. For the above eight households that discontinued kerosene lighting due to the risk of accidents, the risk manifests itself as a threat to their lives. Consider the explanations of participants H27-IT and H17-IT:

“That was before (when I used the kerosene lantern) but not now. When the thing wanted to cause problem for me because it caught fire. You understand. I now stopped using it—I don’t know, maybe because they are mixing fuel or some other thing. It caught fire, it nearly burnt down my place” (H27-IT October 2014)

“Yes I used it [kerosene lantern] well [a lot]...It’s up to ten years (since I stopped using it in this) same house...(I stopped using it) due to my children and the flames coming out from it” (H17-IT October 2014)

The *experience* of participant H27-IT is not uncommon in Nigeria. Studies have indicated many reports of adulterated kerosene in the country, increasing the incidents of explosions, fires, and burns, in addition to the other health risks associated with kerosene (Mills 2016). Women and children are most vulnerable to the health and safety effects of kerosene use, due to the amount of time they spend in the vicinity of the energy service and the increased vulnerability of children to hazards (Mills 2016); thus, the quote from the latter participant indicates a *perception* of these risks, perhaps stemming from experience or knowledge, that led to him making the decision to discontinue use.

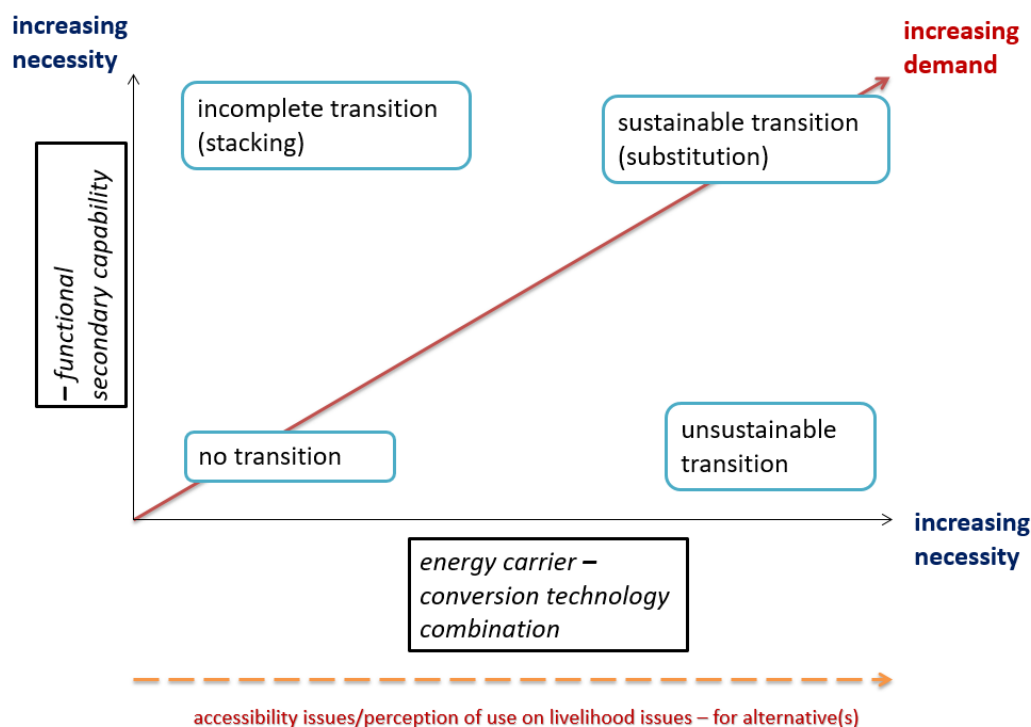
Nevertheless, there remained 33 households who were not deterred by the risks associated with the kerosene lantern, as they continued to make use of the technology. As mentioned in Section 7.3.1, some acted to manage the associated risks by only making use of the kerosene stove outside, or in areas where stationary lighting was required; but still others made use of this lighting as they slept, when the risk of accidents with an unsupervised energy service is higher. Just as with the fuelwood cookstove, the difference lies in drivers of energy decision-making that are associated with the personal context of the household, which will vary widely. For some households, the threat of an accident is too great and cannot be managed, so the energy solution is discontinued depending on the accessibility of alternatives; for other households the threat can be managed with certain behavioural changes that limit the risk to an acceptable level, so use can be maintained; for other households the perception of danger from the risk associated with the kerosene lantern is limited and not enough to produce change. The reality is that for each household, an appreciation of the threat the fuel-technology combination poses to the sustainability of their livelihood

varies, and thus leads to different actions.

Without the marketing of battery torches amongst vendors in most community centres, and rechargeable lanterns in some of the trade markets (Epe town, Ejirin, and Itokin's Sunday market), the access to alternative stand-alone lighting services would have been limited for some households, and therefore produced limited transitions. But without the perception of the livelihood threat the kerosene lantern posed to some households, sustainable complete transitions would have been limited. Certainly, as mentioned under the previous (sustainable complete cooking transitions) subheading, some households can make a substitution transition for other reasons absent the threat to their livelihood; such as the desire for technically superior solutions. However, the varied nature of such a response can lead to widespread instances of incomplete transitions; as is present in the communities interviewed. When traditional energy services become incompatible with what is required to sustain the average livelihood (or life) of the energy poor, sustainable complete transitions can be more widespread. The above experiences confirm that 'increasing necessity' of an energy carrier or conversion technology — as used in the framework — comes not only because of exclusivity (such as with electricity in the case of mobile phone charging), but also when alternatives are inaccessible or the use of alternatives are perceived to be incompatible with sustaining household livelihoods (see Figure 7.2).

Incompatibility based on the urgency of non-use for livelihood sustenance in view of individual experience or perception, as illustrated in the examples of kerosene discontinuation above, can vary from household to household. But the key to a wider spread of traditional energy service incompatibility is *accessibility*. Accessibility is the availability and affordability of an energy solution in view of a household's organisation of daily life and livelihood priorities, under limited livelihood resources (see Section 7.2.1). Most kerosene lanterns supplied in the case region are constructed locally and therefore very cheap, but also more polluting and technically inferior to the hurricane kerosene lamp (see Figure 7.3). If, for example, local artisans can be encouraged to discontinue supply of those technologies, just as greater availability and affordability to cleaner lighting services is being facilitated, then households would find kerosene lanterns *inaccessible* regardless of the nature of each one's personal context. Some of the policy and strategy considerations associated with this, and with other insights presented in the Sections 7.2 and 7.3 are discussed in the next section.

**Figure 7.2:** Framework illustrating the effect of inaccessibility and negative perceptions of fuel-technology alternatives on the necessity of a given fuel-technology, and hence transition outcome



Source: Author's depiction

*Note:* Depiction shows that a market offering a range of energy solutions for a given energy service suggests that each one should be non-urgent. However, one or more energy solutions can be inaccessible when it is incompatible with a household's lifestyle and livelihood resources, or its use can be incompatible with efforts to sustain the livelihood of the household; leaving other energy solutions to be of increasing necessity to fulfil the respective secondary capability. When the secondary capability is urgent, then a sustainable complete transition is the outcome.

**Figure 7.3:** Locally constructed kerosene lantern



Source: Author's pictures (November 2013)

## 7.4 Policy considerations for sustainable energy access

Sections 7.2 and 7.3 have presented the insights obtained in the field regarding the energy service decision-making of households from diverse communities in rural Lagos, and some of the reasons for observed transitions in the case. It was shown that at the centre of household energy service decision-making is the aim of sustaining their livelihood (or lives and lifestyles); which is also at the centre of other non-energy decisions households make with periodic engagements or one-off engagements. The manner in which they organise their lives from day to day, week to week, month to month, and the livelihood resources available to them (human, financial, natural, social, physical) can facilitate or restrict their decision to engage with the acquisition and use of a fuel-technology combination. It was found that sustainable energy transitions took place, when an accessible modern (or transitional) energy service was deemed a necessity because the traditional alternative was no longer accessible, according to the household's livelihood resources and the urgent requirements for sustaining their livelihood; or in some cases when experience with/perception of the traditional energy service threatened household livelihoods. This section will consider some of the changes to the external environment of the case, by which these dynamics can be fostered to bring about sustainable complete transitions to modern energy services.

### *Affecting modern energy access*

Whether grid, mini-grid, multiple-output stand-alone systems, or single output stand-alone systems are used to address energy poverty, there are a number of features that can aid their access. Firstly, infrastructure development is critical; through national plans for connectivity and productivity, and state and local government plans for community integration and market access. The telecommunications-aided success of mobile money is an indication of the importance of infrastructure; this is true for its other forms, and is important for local involvement and capacity building.

Developing local learning and capabilities is an important aspect of contextually-suitable technology, and service availability and affordability; through cost reductions and local support services. As seen with the kerosene lantern in the communities visited, local craftsmanship, local household demand and therefore community-based kerosene marketing, all reinforce the presence of one another and contribute to the high reliance on the energy solution. The same is true for the lifestyle integration of fans for those with significant experience of its use, having been surrounded by its accessibility and the environment to ensure continuous accessibility. This local learning and capabilities development is most possible through a concerted effort in the enablement of technology (and knowledge) transfer — transnational, interstate and intrastate — which requires infrastructure to facilitate the mobility of technology and labour (Cook 2011, Zhang & Gallagher 2016). The technolog-

ical development process that stand-alone energy technologies must go through to obtain a market presence that responds to the social and cultural context, and dynamic nature of household energy use, requires domestic influence on the technology development cycles. Furthermore, all energy technologies or infrastructure require some form of maintenance, which makes market or community access via road, water, or air (contextually-relevant cable car) important. As experience from Oriba showed; absent such connectedness, unsustainable transitions are likely, if any transition at all.

Secondly, in accordance with developing infrastructure and local capabilities — which will aid the utilization of locally available resources — the cost of energy access needs to be tackled on multiple fronts. While technological developments with super-efficient appliances can decrease the cost of energy access, the extent of this benefit will vary across countries. Given the poor state of Nigeria's currency exchange rate, imported goods are very expensive to local consumers (see Chapter 6). Tax exemptions or the use of subsidies have a history of mismanagement in Nigeria, and have proven to be of least benefit to the poorest. If a lack of suitable acquisition and a negative perception of livelihood integration adversely affect the reach of these technologies to the poorest and most vulnerable, then the cost-benefit of such policy measures may not be justified.

Despite the ubiquitous urgency of the lighting and cooking energy services to all households globally, the use of modern fuels and technologies to fulfil these services are not the most urgent concerns of a household as it seeks to sustain (and develop) its livelihood. If the cost of living can be lowered through gains in state and national transportation, affordable and reliable energy to industry for increased domestic production of goods — all increasing productivity for, and access to, cheaper services and limiting the reliance on importing critical goods — then the competition with modern energy for limited household income from food, water, transportation, mobile credit, and household washing materials can be lowered to influence household flexibility in energy decision-making. Making modern energy more affordable will require developing local expertise and industry development in relevant areas of the value chain for strategically selected technologies and resources; resources which are in abundance in Lagos, and Nigeria at large (see Section 6.3.4). This will be a difficult task, requiring concerted action; but as exemplified by China, the effective development of local content over many years can lead to industry development (see Section 3.4.1), which can aid other ECOWAS countries.

### ***Affecting modern energy adoption/use and traditional energy non-access***

In addition to activities taken to make modern energy services available and affordable to local communities, there are other aspects required to ensure modern energy adoption/use



become synonymous with local lifestyles; such that energy stacking is not the long-term outcome, and that actions benefit the poor. Getting households to perceive the trade-off of *using* traditional energy services as being unsustainable to their livelihood is an important part of achieving their discontinuation; but one that is difficult to achieve because of various reasons e.g. myopia (see Chapter 3). Thus, it was observed that the transition away from traditional energy use can be more widely accomplished if its respective energy carrier–technology combinations were inaccessible, rather than through negative perceptions of use on livelihood sustainability; because the recognition of the latter can vary more widely from person to person and from household to household. The result of education can be very subjective.

Any government attempt to restrict access to fuels and/or technologies that combine for poor energy services can be impractical (e.g. in the case of freely collected fuelwood and local three-stone or welded stoves); particularly given the informality of rural Lagos and beyond, as well as the weak administrative and enforcement capacities in the country. But it can also infringe on the energy equity and justice of the poor, who might be worst affected (e.g. a removal of subsidies on kerosene amidst unsecure and exploitative distribution channels), and can lead to unexpected outcomes (greater reliance on fuelwood cooking due to increased cost of kerosene, as evidenced with participant H44-IT in Section 7.3.3). But a transformation that leads households to make the personal decision to restrict their access to traditional energy services can better achieve lasting results. This is possible through changes to the organisation of daily life for the average energy poor household. The vocational activities of household members, the activities children are committed to on a daily basis, the regions and markets adults visit on a daily, weekly, and monthly basis, all have an impact on the *practical availability* consumers have to energy carriers and their respective conversion technologies (and technology support services). These activities can draw from the types of institutions, and social and occupational networks households engage with; connections that are an important source of shaping knowledge, customs, perceptions, and access to resources for livelihood support (Sehpal et al. 2014).

The practice of smallholder farming for many rural locals in Epe, and in other regions of rural Nigeria, is an important driver for households to maintain the practice of freely–collected fuelwood for cooking purposes. Nigeria, and in particular Lagos, has seen growth in its services sector with limited productivity and development in its agriculture and industry sectors; where there is high potential for growth and jobs. The mechanisation of farming and development of the agri-food processing chain that will add value and productivity to Nigeria’s agricultural sector needs to be accompanied with the development of other industries and service jobs in strategic regions across the country. This will allow rural dwellers to obtain non-farming job opportunities as the demand for farm work decreases

with mechanisation. Without strategic planning of sector development across the country, there is the possibility of further population pressures on regions like metropolitan Lagos that have led to the state's slum problem. Furthermore, acceptance of mechanisation and the consolidation of farm plots can face indigenous opposition if other opportunities for work are absent. Indeed, such changes might require careful and patient handling, as the prospect of occupational change to what is a crucial aspect of cultural, personal and livelihood identity will likely face opposition. Approaches focusing on the education and encouragement of the younger generation towards non-farm work can have greater chance of success, as the older generation might maintain:

“(I practice) every farming work (in addition to smallholder farming). Both fishing, both hunting. If you go inside my house now I will bring my hook that I use to fish. It's the CERUD work [security guard] that stops me from doing it much...That is my real (work)—The three are my three occupation—Fishing, hunting, farming. That is my life...I will never change” (H13-IG September 2013)

The prospects of higher incomes from formal non-farm work can serve as an attraction however, for younger rural dwellers and for parents to encourage their children in education and training for such jobs; through which the modern energy services that become more urgent to them — because of increasingly inaccessible traditional energy services — can be more affordable. As modern energy exposure and experience influence perceptions around the urgency of use for livelihood sustainability, energy decision-making in favour of modern energy services and away from traditional energy services can be strengthened by a mutual feedback loop (Goldthau & Sovacool 2012). For example, social and occupational activities in the informal sector currently do not place much emphasis on having ironed clothes, on a daily basis. Therefore, a local can still have self respect and respect from others even if their clothes are not pressed with an iron (H67-IT, H64-IT). But as work becomes more formal, and people become more exposed to ironing services, the requirements for achieving the ‘respect’ secondary capability will likely change. Nevertheless, modern energy market spoilers must be avoided (e.g. a lack of awareness and education; lack of training leading to negative experiences and perceptions as in the case of LPG; or flawed technology in the marketplace).

It is also important to capture gender neutrality in such vocational transformations with the younger generation. It is clear from insights that when women are busy undertaking productive non-farm work, there is an opportunity cost to engaging in fuelwood collection. But if men are the main beneficiaries from working more productive jobs, women — particularly housewives in rural areas — will still have the human capital to engage with fuelwood collection; even if they are not farmers (see the experience of participant H31-IG

in Section 7.2.1).

Finally, and perhaps most importantly — given its role at the centre of ensuring the preceding actions discussed are effectively and consistently implemented in the short, medium and long term — is the facilitation of trust across all stakeholders in the household energy transition process. Confidence in the transformative process across politicians, government agencies, public institutions, private sector, local communities, civil society, and other communities of interest and stakeholders is necessary for the many activities that must take place across a range of interconnected sectors in order to bring about the necessary changes in external and personal contexts of households. Fostering unity in goal and action, in a country that has a history of division across many social, cultural and political issues, will be necessary to garner trust. Although religious and ethnic differences fuel domestic geopolitics, energy poverty is an issue all states in Nigeria can relate to, and *perhaps* form a basis for unity.

But strategic planning, funding and direction on energy access must be led by the federal government, and firmly rooted in national and state development plans. Legislation to allow greater decentralization of energy and development activities will require federal action. The transparency and accountability in processes across a range of sectors including trade, land, natural resources, amongst others, is important to building trust and momentum; and again, requires action that begins at the federal level. Rapid development of the capacity at all levels of government to administer its responsibilities, and ensure efficiency and equity in the transformations that will take place is an important step (e.g. avoiding disputes and ensuring equitable land transactions as productive gains in agriculture is pursued). Without such leadership and evidence of change, the distrust that works its way from politics, through society, through to energy-poor households — that lead them to believe it is the government's duty to provide cheap (or free) access to modern energy services — can serve to hamper transition efforts and development.

Many of the above policy and strategic considerations outlined in this section might seem unrelated to the core business of financing and supplying the technologies and services needed for energy consumption over time, but they all impact the environment in which households make their energy service decisions; and thus, the sustainability and effectiveness of any energy access solution.

## 7.5 Conclusion

This chapter has shown that the energy service decision-making of the energy poor is based on a complex set of influences that cut across the different consumer interactions with the various dimensions of an energy service, and the livelihood resources they are willing to trade-off to ensure they can sustain or progress their lives. Given the centrality of a

person's vocational activity on how they organise their daily lives and the livelihood resources available to them (including, and beyond their financial capital), it serves to be a major driver of energy service availability and affordability, *in practice* — that is, beyond the classified social and economic characteristics of a household. Modern energy exposure begets modern energy use; which over time can serve to reinforce this socio-technical regime to be an important component of local lives. The same is, and has been true for traditional energy services. In the case region, some households discontinued kerosene lantern use due to the dangers associated with the energy service, but many maintained its use. Such a reason for energy service discontinuation can be subjective, and is likely the reason why other households maintained a different risk–reward profile for the energy solution. A more objective reason for fuel–technology discontinuation can be inaccessibility for acquisition or use; as was experienced by those in rented accommodation without an outdoor kitchen by which they could engage with fuelwood cooking.

Thus — without encroaching on the freedom of energy solution choice for households — if traditional energy services can become inaccessible to the energy poor, while modern energy services are increasingly being made accessible, then sustainable complete transitions can take place. The most effective way of achieving this is through a transformation of the organisation of daily life for the average energy–poor household. The strategies required might make the process of change longer, but they will be more pervasive and sustainable. Insights from the field suggest that for the energy poor to substitute traditional energy services by modern energy services, we need to change people's lives to use modern energy services. Chapter 8 will explore a set of scenario–pathways for the future external environment of Lagos and Nigeria using the Lagos–LEAP model introduced in Chapter 5, to produce insights about facilitating sustainable household transitions to modern energy services.

## Chapter 8

# The Lagos–LEAP Household Energy Demand Model

*How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways of relevant drivers, and what can this inform about facilitating the transition to modern energy services?*

**Research Question 3**

## 8.1 Introduction

Chapter 7 presented insights from a qualitative assessment of the energy service decision-making of the energy poor and the nature of their transitions to reveal the centrality of a person's livelihood organisation and resources, in what is a complex phenomenon. The final research question aims to draw on this observation to examine scenarios of household energy transitions in Lagos state to reveal policy/strategy insights. This question will be answered using the purpose-built Lagos-LEAP model, which was introduced in Chapter 5. A reminder of key distinctive aspects about the model include:

1. Its holistic treatment of household energy services to capture trade-offs and synergies in changes to the energy dimensions of different energy services.
2. Its highly disaggregated model structure to capture 44 profiles of household energy consumption describing current and alternative/future energy behaviours.
3. Its consideration of load shedding and private electricity generation, and their combined impact on household energy behaviour.
4. Its dual interpretation of category and subcategory household changes to denote both absolute change in the socio-economic classification of a household, as well as changes to the organisation of a household's daily life to influence energy behaviour, notwithstanding absolute change in household classification.
5. Its use of scenarios to present consistent storylines about social and economic development (external environment) in Nigeria and Lagos; all of which are projections for the purpose of answering the research question, rather than forecasts. The scenarios are also not being examined for selection, as the most desirable scenario will be clear from its stated narrative and driver assumptions; rather they serve to provide varied circumstances that lead to different progressions of household energy demand to learn from.

As Chapter 5 elaborated, the above characteristics of the model have all been incorporated for the purpose of answering research question 3, with a process that: considers some of the salient aspects about household energy demand in developing countries that are seldom considered in existing models; captures aspects of the conceptual understanding of the household-energy interaction that are sometimes overlooked in quantitative analyses (e.g. cross-service interaction); and provides insights that pertain to policy/strategy implementation, rather than policy selection that often assumes effective implementation. This chapter will reveal insights that are relevant to Lagos and Nigeria, but also to other contexts, about the most effective forms of energy for sustainably addressing energy poverty, and other opportunities and pitfalls of energy policy and strategy.

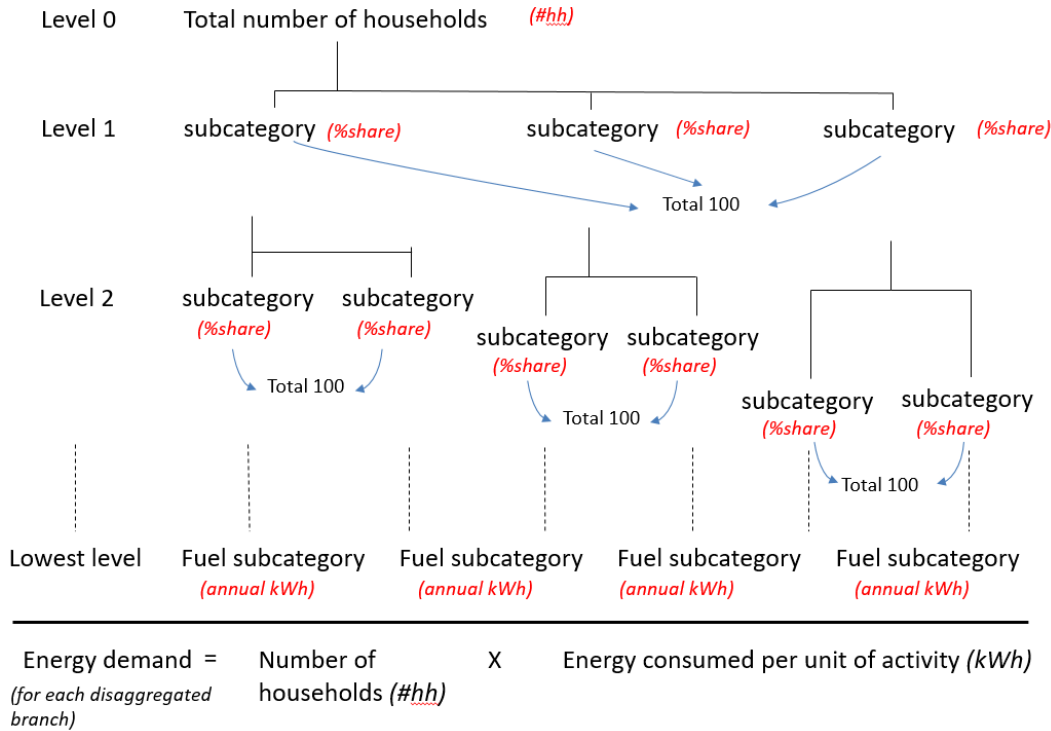
The rest of the chapter is structured as follows: Section 8.2 will present the variables, data and assumptions made to develop the Lagos-LEAP's model database and structure. Section 8.3 will describe the scenario drivers used in the model, their indicators, and how they interact with the model variables. Section 8.4 describes the four scenarios modelled in this work and their pathways, before Section 8.5 touches on the main limitations of the model. Finally, Sections 8.6 and 8.7 respectively present the results of the examination and conclude the chapter.

## 8.2 Model variables, data and assumptions

In discussing the variables, data and assumptions used in the Lagos-LEAP model, it is worth briefly recounting how the model operates, as explained in Chapter 5. The model makes use of LEAP's simple energy accounting feature which accounts the product of activity (number of households — for the residential sector) for each branch of the model structure and the energy consumed by the energy devices at the lowest level of each branch in a given year. Parameter changes in the share of households and/or energy consumption between the base (2010) and end years (2043) of the model provide a projection of household energy demand in a given scenario. As discussed in Section 5.4.3 and depicted in Figure 5.4, Lagos-LEAP is structured such that energy consumption parameters in the model are fixed for all scenarios; where all possible current and future energy consumption behaviours have been captured in 44 sets of annual household energy consumption profiles. Variations in annual accounting, and thus model projections, are therefore based on changes in the share of households across the 44 energy consumption profiles from year to year. Therefore, the only *variables* for every year in each scenario for the energy accounting calculations are the *% shares of households* in each subcategory at every category-level of the model structure that disaggregate to make a model branch (see Figure 8.1).

In this scenario exercise, changes in the parameters of household shares (*dependent variables*) are driven by a selected set of scenario indicators denoting the external environment of Lagos and Nigeria (*independent variables*), the annual parameters of which vary in each scenario and have been stated in accordance with the narrative of each scenario. These independent variables, their data, drivers, and their relationship with the model's dependent variables are treated outside the model's accounting calculations, and are discussed in Section 8.3. The resulting annual changes in the parameters of the dependent variable for each scenario serve as inputs to Lagos-LEAP for accounting. The model requires secondary data on base year household shares for every category of the model structure, and data to develop a database of current and future energy consumption possibilities in the state that consider the selected categories of the model structure. The selection of categories/variables used in the model was therefore subject to the secondary data available; and a number of

**Figure 8.1:** Lagos-LEAP annual energy accounting calculation



Source: Author's depiction

Note: The above schematic illustrates the generic structure of Lagos-LEAP. The actual structure has 7 levels and 44 energy consumption profiles that consist of 376 ways in which 23 technologies are used at its lowest level (see Section 5.4.3 and Figure 5.3).

assumptions were also necessary in developing the energy consumption database according to each row of subcategories that make up a branch in the model. These considerations are discussed in the sections that follow.

### 8.2.1 Model variables

This section outlines the dependent variables only; which are the categories and subcategories along the model's hierarchical structure that hold varying *annual percentage shares of households* in each scenario, and are used in accounting annual energy demand in Lagos. The purpose of the categories that make up the structure of the Lagos-LEAP model is to capture social, economic and technical characteristics of households, that can serve to represent a particular influence on a household's organisation of daily life; which incrementally, leads to a particular interaction with energy services. Discussions in Chapters 4, 5 and 7 showed that a household's organisation of daily life is determined by influences of a personal and external nature, including their individual contexts, and thus do not conform wholly to socio-economic groupings (see Section 7.2). While this can be acknowledged and considered in analysis of a more social, qualitative and individual nature as was conducted in Chap-



ter 7, the quantitative modelling work in this chapter, working with the entire population of the case region (Lagos), must assume similar behaviour for demographic groupings, and categorise as such (see footnote 9 in Chapter 5).

As permitted by data availability, the categories (and subcategories) selected to make up the model structure, initially introduced in Figure 5.3, are:

- (i) Level 1 — settlement (urban non-slum, urban slum, rural).
- (ii) Level 2 — income (high (>US\$22), medium (US\$18–22), low (US\$4–17), poor (<US\$4) — all in 2010 US\$ per day).
- (iii) Level 3 — availability of reticulated electricity (base, high).
- (iv) Level 4 — energy consumption efficiency (base, efficient).
- (v) Levels 5, 6 and 7 — end-use service, conversion technology, and primary/secondary fuel respectively, that together make the annual household energy consumption profile.

The above categories and subcategories are defined in Section 8.2.2.

At level 1, the settlement category captures the influence of living conditions on the household–energy interaction. At level 2, the income category distinguishes between the state of energy affordability in each settlement and the resulting influence on the household–energy interaction. Level 3 distinguishes between the household–energy interaction when networked grid or mini-grid electricity provision to each settlement is at base-year levels (*base*), and an option for the possible provision of higher average hourly availability of networked electricity to each settlement (*high*). The manner in which this relates with private electricity generation and the branches stemming from levels 1 and 2 are discussed in the sections that follow. At level 4, the model distinguishes between the household–energy interaction when energy consumption attributes such as duration of use, energy carrier and conversion technology are relatively inefficient and/or unclear (*base*), and when there is relatively increased efficiency and/or cleaner attributes of energy consumption (*efficient*) for each disaggregated branch stemming from levels 1, 2 and 3. Finally, levels 5, 6 and 7 distinguish between the different combinations of energy services, energy carriers, conversion technologies, and the nature of use that make up the annual energy consumption profile at each of the 44 branches of energy behaviours disaggregated at level 4.

## 8.2.2 Model data and assumptions: Base year household distribution and energy consumption database

The energy accounting undertaken in LEAP to project energy demand in each scenario, required model input data on annual household percentage shares at every level of the model structure between 2010 and 2043 for each scenario, as well as data to construct the

fixed database of possible household yearly energy consumption profiles. Base-year (2010) shares of household at each level of the model structure is based on data from secondary sources, and is the same for all scenarios. For the years 2011 till 2043, household shares input to the model are based on generated data and assumptions made in accordance with the driver specifications in each scenario (covered in Sections 8.3 and 8.4). In order to build the database of energy behaviour, statistical information of energy use corresponding to the selected subcategories at each level of the model structure was required. Therefore, the final categories and subcategories selected — as outlined in the previous section — considered the availability of data across the two dimensions of LEAP’s accounting exercise (see Table 8.1).

**Table 8.1:** Lagos–LEAP input data

Input	Type of data	Model structure level	Category	Data treatment	
				Base year data	Input data for annual snapshots till End year
Variable social, economic, and technology characteristics	Annual distribution of households (% shares)	Level 0	Household population	2010 Lagos data	Assumed UN projection
		Level 1	Urban and rural population	2006 Lagos data extrapolated for 2010	Exogenously estimated according to scenario drivers
		Level 1	Slum population	1995 and 2006 Lagos data extrapolated for 2010	Exogenously estimated according to scenario drivers
		Level 2	Income categories	2010 Lagos data	Exogenously estimated according to scenario drivers
		Level 3	Reticulated electricity availability (base or high)	Assumed 100% base category	Assumed
		Level 4	Consumption efficiency (base or efficient)	Assumed 100% base category	Exogenously estimated according to scenario drivers
Database of energy consumption (intensity) profiles	Annual energy intensity (kWh)	Levels 5, 6 and 7	Profile of energy consumption per end-use, energy carrier and conversion technology for the 44 branches that stem from levels 1 to 4	<i>Fixed possibilities</i>	
				Exogenously calculated based on secondary data	

Access to quality data on the social, economic, technology, and energy use situation at the local and state level of Nigeria is difficult to come by, and is one of the reasons Lagos was selected as the case for modelling work; as it possesses better data availability than other areas of the country. As a result, model data was obtained and collated from a variety of sources, as is often required in models built for developing countries (McPherson & Karney 2014). Key data sources include those obtained from the Lagos Bureau of Statistics (e.g.

the Lagos Household Survey 2010, LBS 2010), which is the leading statistical agency in the Lagos state; and the Lagos State Electricity Board (LSEB), which is the state ministry of energy’s implementing agency. A detailed account of the model data sources and treatment can be found in Tables D.1 and D.2 in Appendix D. The secondary data relied on were largely based on representative samples of the case population, but some sources provided different degrees of explanation of the methods utilised in data collation or generation; a few of which provided no information. This, in addition to instances of missing data, made it necessary to calibrate the data with multiple sources. Some of these treatments are discussed below.

### ***Base-year data on percentage distribution of households***

As Table 8.1 shows, base-year data of the percentage distribution of households was obtained from secondary sources for categories such as household population, settlement population shares, and income across levels 0, 1 and 2. Regarding the household distribution at levels 3 and 4 — on base or high reticulated electricity availability and base or efficient consumption efficiency respectively — 100 % of households are assumed to be in the base subcategory respectively, in accordance with the disaggregated consumption profiles detailed for 2010. High and efficient categories for the two levels respectively present possible consumption profiles following improvements in energy provision and consumption, irrespective of change in the social and economic status of the household. For the other levels, data from various sources were largely consistent, but for the instance of the state population.

#### **Level 0**

There was a wide disparity on estimates for the state’s population in the base year, which ranged from circa 19 million residents according to state estimates, to circa 10.9 million residents in UN estimates (UN-Habitat 2013, LBS 2010). It is difficult to know the source of this disparity. However, since state population figures are a source of political interest in Nigeria — given they have implications for federal budget allocations (Bloch et al. 2015, World Bank 2015c) — the model sought to utilise a figure of a neutral source (10.9 million: UN estimate) as its total population estimate in the base year. Nevertheless, the figure used in the model has negligible influence on model results, as evaluation is based on relative changes as opposed to absolute figures.

#### **Level 1**

The distribution of the state population across urban non-slum, urban slum and rural areas was confirmed using state household surveys, national statistical data, World Bank data, and data from peer-reviewed publications (World Bank 2006, Agbola & Agunbiade 2009, LBS 2010, NBS 2012). Calibration was necessary due to varied data forms that included; local government population, settlement shares for local governments, state settlement data

that predated the base year 2010, etc. The populations of all local government areas (LGAs) in the state presented in the 2010 state household survey were adjusted for the population figure used in the model. The survey distinguished between proportions of each LGA that were attributed rural or urban. Data from Agbola & Agunbiade (2009) provided population data on all recorded slums in Lagos linked to their respective local governments. To obtain estimates of the slum populations within respective LGAs, it was assumed that the population growth of the identified Lagos slums in 1995 would grow at the same rate as the state population between 1995 and 2010.<sup>1</sup> The final settlement household shares used in the base year of the model can be found in Table 8.2, following their adjustment for the number of households, according to data estimates for household sizes across selected settlements and income groups. In total the model estimates circa 2 million households residing in Lagos state in 2010. Slum households refer to illegal structures, overcrowded regions/with dilapidated structures, or areas lacking access to critical services such as sanitation (Agbola & Agunbiade 2009, Lukeman 2014).

## Level 2

The income categories utilised in the model, distinguishing between the high, medium, low, and poor subcategories, were calibrated using a number of sources. These included: the survey and statistical data used in level 1; data from studies conducted at the national level by private and multilateral organisations (Accenture 2011*b*, MTI 2013); and studies measuring the size of the BOP market (Hammond et al. 2007). The subcategories were selected to coincide with the main divisions of energy behaviour found in state survey data and survey data by multilateral organisations. These sources of data on energy behaviour used differing income classification methods, including differing currencies and income ranges, making it necessary to calibrate their attributions and standardise them to be used in Lagos-LEAP. Final categories (in 2010 US\$) as previously indicated in Section 8.2.1 were: high (>US\$22/d), medium (US\$18–22/d), low (US\$4–17/d), poor (<US\$4/d).

The 2010 state household survey provides data on population shares for each income group across each LGA. This was used in conjunction with estimates on settlement populations from level 1 to determine the household shares across the adopted income groups in each settlement. The resulting distribution of Lagos' households across the subcategories of levels 1 and 2 in the base year of the model are presented in Table 8.2. Based on the data, the slum subcategory in level 1 is disaggregated to the medium, low and poor income-subcategories only, at level 2 (Agbola & Agunbiade 2009, LBS 2010, Lukeman 2014).

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<sup>1</sup>Standardizing adjustments had to be made on the final estimates for settlement proportions so as to maintain parity with official estimates of the slum proportions within Lagos state (circa 60 % in 2010). This was because calculations using the LGAs led to a lower estimate of the proportion of households residing in slums than is typically cited for the state (World Bank 2011*a*). The reason for this discrepancy in calculations likely stemmed from the extrapolation calculations made, or from the difference in slum definitions utilised by various estimates.

**Table 8.2:** Household settlement and income distribution in base year 2010

			<i>Percentage share of households (income distribution)</i>				
			<b>Poor</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>	<b>Total</b>
<i>Percentage share of households (settlement distribution)</i>	33	<b>Non-slum</b>	23	48	24	5	100
	58	<b>Slum</b>	26	71	3	-	100
	9	<b>Rural</b>	35	48	15	2	100
			100	<b>Total</b>			

### ***Database of energy consumption profiles***

The database of possible annual energy consumption profiles was developed using state survey data, state electricity audit data, official state power supply and fuel distribution records, other developing country technology consumption data, global and regional technology trends reports, primary observations in the field, and expert stakeholder meetings (see Table 5.3). Data sources provided details on attributes such as: the existing stock of appliances in Lagos households and nature of use according to different user groups (UN-Habitat 2008, Accenture 2011*a*, LSEB 2013, Upadhyay et al. 2013, UNDP 2013); disaggregated electricity supply statistics and private electricity generation data for the state (LBS 2010, Eko DISCO 2013, Ikeja DISCO 2013, LBS 2013, Upadhyay et al. 2013); and assumptions made about possible future technology use in the state (Bardouille 2012, Frankfurt School-UNEP Centre/BNEF 2013, Fridley et al. 2013, IEA 2014*a*, IRENA 2015, stakeholder meetings). A detailed treatment of the data used can also be found in Tables D.1 and D.2 in Appendix D.

Household disaggregation from levels 1 to 4 of the model structure produces 44 branches that denote a particular form of household organisation of daily life, and thus interaction with energy. As Table 8.1 shows, this energy interaction is captured through the various energy services, energy technologies and energy carriers used by a household (levels 5, 6 and 7 respectively) that combine to form the annual energy consumption profile for each of the 44 branches. According to the subcategories that form each branch there are differences in energy interaction based on the following attributes:

#### **Electricity supply and demand attributes**

- different average hours of reticulated electricity supply *availability* per day to each settlement subcategory at level 1;
- therefore, different average hours of private electricity generation *required* per day to cover shortfall for each settlement subcategory at level 1;
- and different average hours of private electricity generation *capability* per day to cover shortfall for each income subcategory at level 2.

The above attributes combine to affect the average total amount of electricity to the various household groups per day; which is captured at disaggregation up to level 3 of the model structure. The final attributions can be found in Table 8.3.<sup>2</sup>

**Table 8.3:** Hourly attributions of electricity supply at disaggregation up to level 3

	BASE-level hours of reticulated electricity availability ( <b>Level 3</b> subcategory)											
<b>Level 1</b> Reticulated electricity (hours per day)	<i>Urban Non-slum</i> 6				<i>Rural</i> 1				<i>Slum</i> 3			
<b>Level 2</b> Private electricity generation (hours per day)	<i>High</i> 10	<i>Medium</i> 5	<i>Low</i> 3	<i>Poor</i> 2	<i>High</i> 10	<i>Medium</i> 5	<i>Low</i> 3	<i>Poor</i> 1	<i>Medium</i> 3	<i>Low</i> 2	<i>Poor</i> 1	
	HIGH-level hours of reticulated electricity availability ( <b>Level 3</b> subcategory)											
<b>Level 1</b> Reticulated electricity (hours per day)	<i>Urban Non-slum</i> 22				<i>Rural</i> 6				<i>Slum</i> 12			
<b>Level 2</b> Private electricity generation (hours per day)	<i>High</i> 2	<i>Medium</i> 0	<i>Low</i> 0	<i>Poor</i> 0	<i>High</i> 10	<i>Medium</i> 5	<i>Low</i> 3	<i>Poor</i> 2	<i>Medium</i> 3	<i>Low</i> 2	<i>Poor</i> 1	

### Private electricity generation technology attributes

- different generation technology based on income subcategory at level 2;
- and different generation technology based on consumption efficiency subcategory at level 4.

The above attributes differentiate between the use of diesel-fuelled generators by higher-income households, whereas other lower-income subcategories make use of gasoline-fuelled generators, which are limited in the loads operable. The above also differentiate between the possibility of cleaner private generation (efficient subcategory at level 4) from the base case with use of solar and inverter technology backup systems.

### Energy service attributes

- different electricity-based service possibilities according to electricity supply and demand attributes, and private generation technology attributes outlined earlier;

<sup>2</sup>These are estimates of average levels based on secondary data (LBS 2013, Upadhyay et al. 2013, NBS 2014, NOIPolls 2015), because in reality the availability of electricity from the grid for a particular region as a result of load shedding is not constant per day and can differ between days, weeks and months. Furthermore, a proportion of households in each region may not be connected to the grid at all (e.g. in rural areas), which is considered in the average daily hours attributed. This is the same treatment used for private generation estimates.

- and different energy service demand according to income subcategory at level 2.

The distinctions made in this area draw on distinctions of previous attributes. For example, the energy services a household can engage with is influenced by the urgency of the service and their ability to engage with it; it is also influenced by the loads operable during private electricity generation, according to the generator size/type; and it is also influenced by the total hourly electricity available to a household. These distinctions are made across the disaggregated branches of the model to determine the typical energy service use in each branch, as revealed by the data.

### **Energy conversion technology attributes**

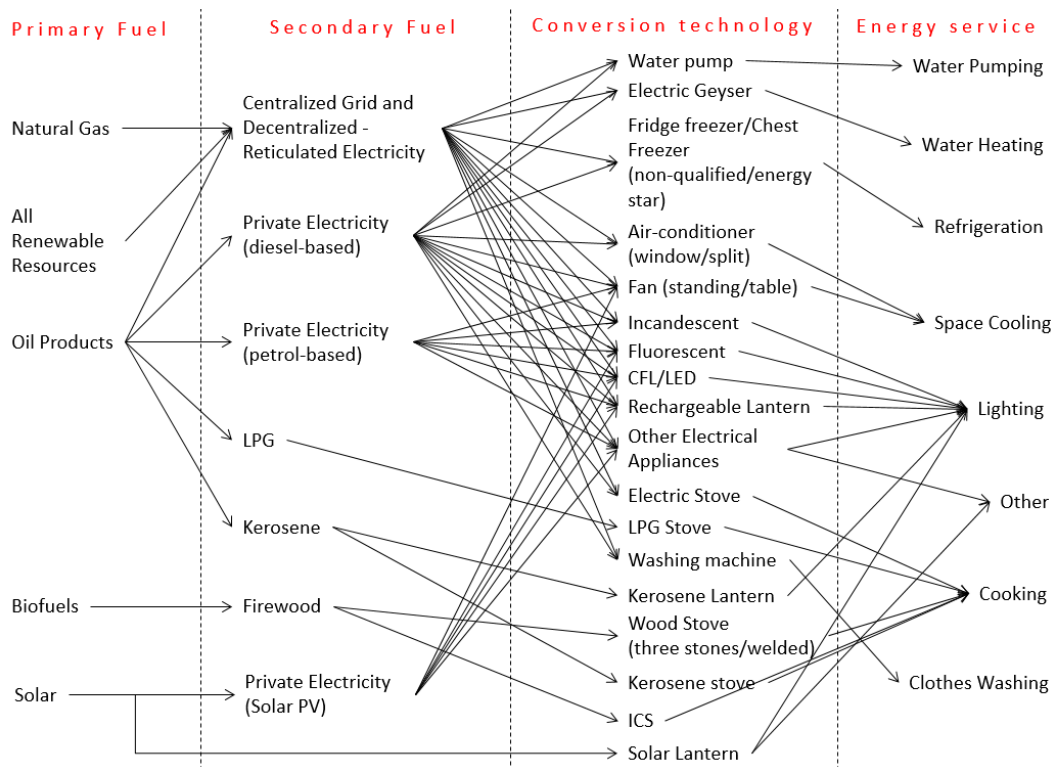
- different electricity-based technology demand profiles according to electricity supply and demand attributes outlined earlier;
- different technology demand profiles according to settlement subcategory at level 1;
- different technology demand profiles according to income subcategory at level 2;
- and different technology demand profiles according to consumption efficiency at level 4.

The effect of all the above attributes on the calculated annual intensity of the 44 energy consumption profiles can be found in Appendix C. It indicates some of the cross-service interactions that are seldom considered in household energy demand models, and the considerations of energy stacking and how it influences the energy demand profiles characterised for each household branch. Figure 8.2 shows the types of energy transformations considered in the household energy profiles that make up the database. A quick example of the significance of the energy transformations considered is the difference between private electricity generated from petrol-based (gasoline) generators and diesel-based generators. The former represents the generator typically relied upon by lower-income households, with capacity restrictions that omit the use of appliances such as an iron, refrigerator, electric cooker, and other high consumption technologies. The energy consumption database accounts for the effects this has on the energy service engagement by the respective household group, and how or whether it is met, as well as any knock-on effects this may have on other energy services and/or fuel-technology engagement (e.g. the lack of refrigeration necessitating fuelwood smoking for food preservation).

Some energy carriers and their respective technologies were omitted largely due to data limitations concerning the share of their respective use in the state residential sector across demographics. These included fuels used for local lighting such as palm oil, candles and batteries. They all represent negligible intensities, and so were assumed to be represented by kerosene lantern use. Some other fuels which had low to negligible presence in the base

year of Lagos' residential sector, but the potential to play major roles in the future of the sector's energy system — such as ethanol for cooking — were also not considered in the model.

**Figure 8.2:** Reference Energy System (RES) for residential Lagos



Source: Author's depiction

Note: Not all conversions illustrated in the RES are present in the base year of the model; but are possible over the model timeline depending on the scenario. For example, washing machines hold a negligible share of the residential energy market in 2010 and are not considered as an energy intensity contributor in the base year of the model.

## Model validation

Given the uniqueness of Lagos-LEAP's modelling structure (e.g. high level of disaggregation), it is difficult to rely on databases collated by other models of household energy demand for the same geographical region. Nevertheless, at the start of model development there did not exist a bottom-up model for Lagos. Since then, energy estimates within the state have been undertaken for policy and planning purposes, and this was used to cross-check the reasonability of the model. Aggregation of Lagos-LEAP's database calculations for the base year (2010) produces a household power demand for the state of 3155 MW. This figure compares well with other estimations; as a project conducted by the LSEB in partnership with the UK's Department for International Development (DfID), using a state population (21 million persons) that was double that of the state population used in Lagos-LEAP, estimated residential power demand for the state in 2012 to be 6564 MW (Atkins/LSEB



2014).

Comparing and calibrating end-use data and assumptions with aggregate consumption data — such as official energy balances — is a useful way of validating bottom-up models (ERC 2013), but energy balances only exist at the national level in Nigeria. The country takes records of fuel marketing across states, but there is difficulty in using these figures to validate model calculations. For example, the national oil company’s statistical bulletin records the annual marketing of household-kerosene undertaken by itself and other independent marketers in Lagos (NNPC 2014); however, the presence of a significant black market for kerosene (see Chapter 6), and the high use of household-kerosene for other commercial and institutional cooking requirements, makes the statistical data incomparable with Lagos-LEAP estimations.

This section explained the structure of Lagos-LEAP and the data used to characterise the distribution of households across the model structure in the base year of the model, and the energy consumption database; the product of which is accounted by LEAP to produce energy demand outcomes for the base year 2010. The household percentage shares across subcategories at each category-level of the model structure are model variables that differ annually for each scenario. These differences signify the influence of the drivers that characterise each scenario on the model outcome. The next section will introduce the drivers utilised in this scenario exercise, their indicators, and how they influence the household percentage distribution at each level of the model structure.

### 8.3 Model drivers and indicators

As introduced in Section 8.2, scenario drivers are used as independent variables that differ according to scenario narratives, serving to influence the percentage share of total households across subcategories of levels 1, 2 and 4 of the model structure (dependent variables). As introduced in Chapter 5, the 44 branches that stem from disaggregation at all levels of the model structure denote a form of organisation of daily life for a household; from which, different energy behaviours result (see Section 5.4.3). Therefore, drawing from discussions had in Chapter 4, the scenario drivers serve to represent the external environment that influence daily life and livelihood resources, and lead to particular household engagements with energy services. As the concepts discussed in Chapter 4 — on the energy decision-making of the energy poor — showed, there are a plethora of socio-cultural, natural, political, institutional, and market factors that make up the external environment that influences household livelihoods and behaviour (see Section 4.2). Rather than consider the full range of factors put forward in the literature — which is impractical — discussions in Chapters 4, 6 and 7, which highlighted some of the most relevant factors observed in other contexts, in Nigeria and Lagos, and amongst local households respectively, were used to select a refined

list of external environment factors that could be used as scenario drivers. It was also necessary for the factors used to be relatable to the categories selected at levels 1, 2 and 4 of the model structure and their subcategories.

The basic explanation of the use of drivers and indicators to generate annual household percentage share data over the model timeline to input to LEAP — which will be discussed and further explained throughout this section — is this:

- (i) Selected subcategories (dependent variables) from the category–levels 1, 2 and 4 are related to particular indicator(s) of relevant scenario drivers (independent variables) as stated in literature and according to statistical significance of historical data.
- (ii) Historical data on the independent and dependent variables are used to determine parameter correlations between the two variables.
- (iii) Each scenario driver and its representative indicator(s) are given different pathways (from base-year to end-year) according to the narratives of each scenario (this is presented in Section 8.4).
- (iv) The indicator pathways (independent variables) and the parameter correlations obtained from historical data, are then used to generate annual household percentage share data till the model end-year for the respective subcategories at category–levels 1,2 and 4 (dependent variables), to be input to Lagos–LEAP.

The next section will discuss the drivers selected. Section 8.3.2 will discuss the indicators used to represent the selected drivers, and the relationships attributed between the driver–indicators and the subcategories at category–levels 1,2 and 4; before Section 8.3.3 explains the method used to estimate parameter correlations and generate the annual household percentage shares over the model timeline that is input to Lagos–LEAP for each scenario.

### 8.3.1 Driver selection

In Chapter 4, some of the most significant drivers of household energy transitions (or lack thereof) from the experiences of countries such as the U.S., China, Vietnam, Germany, Mexico, Brazil, Kenya, and Malaysia, involved factors including infrastructure, local capabilities, multi-stakeholder trust in the goal and action, labour transformations, and others (see Section 4.3). Insights from the field discussed in Chapter 7 also pointed to and explained the influence of some of these factors on household energy behaviour and their transitions. In Chapter 6, some key features that characterise Nigeria’s and Lagos’ external environment in which households make their energy decisions were introduced, and numerous issues relating to the above factors were found; including agricultural unproductivity, a large informal economy, maladministration of key sectors such as land, housing and education, and political

and societal mistrust, amongst others. The selected drivers will have a range of pathways in which they can develop, and be related to the connectivity and formality of households (settlement at level 1), the inclusiveness of development (distribution of households across income subcategories at level 2), and the market presence and uptake of modern technologies (energy consumption efficiency at level 4). Therefore, the following scenario drivers were used:

- Administrative capacity
- Infrastructure
- Economic transformation and productivity
- Law enforcement
- Economic formality
- Domestic purchasing power

#### **Administrative capacity**

This driver pertains to developments in the capacity for public administration from the federal level to local level. It surrounds issues of transparency and accountability that form the bedrock of public service delivery, and in building trust in institutional and market systems and processes (Tankha 2009).

#### **Infrastructure**

This driver refers to the development of infrastructure that affects issues such as connectivity, living conditions and productivity; such as transportation infrastructure and housing. It serves to impact market and information accessibility, the cost of consumer goods and services, and other issues of livelihood security (UNECA 2013).

#### **Economic transformation and productivity**

This driver considers developments in the productivity and diversification of the economy. It touches on aspects concerning the productivity of key economic sectors from agriculture to services, and the development of strategic industries. Overall, it reveals changes in the value and competitiveness of goods and services produced in the country or city, which will have a bearing on the wealth of the people (FAO/UNIDO 2008).

#### **Law enforcement**

The law enforcement driver captures the tools and systems necessary for effective enforcement of the rule of law. These tools and systems include the independence of judicial courts and sector watchdogs, the capability of law enforcement agencies and other institutions to

perform their duties and public recognition and respect of these authorities, and the data infrastructure that undergird monitoring and action (Grindle 2004). These all influence the risks, security, ease, willingness, and therefore nature of supplier and consumer participation in society and the economy.

### **Economic formality**

The driver refers to the impacts of the presence, size and nature of the informal economy in a region. Economic formality, or otherwise, has an important bearing on livelihood aspects such as employment security, wages, consumer access, amongst others (Charmes 2012).

### **Domestic purchasing power**

This driver is concerned with the reach of local incomes (purchasing power of local currency), as influenced by the demand and supply dynamics of goods and services in the marketplace (FAO 2011).

## **8.3.2 Driver and category-level relationships, and indicators**

Given the above selection of some drivers that have been used by econometric models of energy demand — such as drivers pertaining to the growth of an economy — it is worth remembering that the method of projecting household energy demand in Lagos-LEAP does not rely on econometric simulations of energy-related behaviour; such as forecasting the diffusion/uptake of electrical appliances according to estimated relationships (or correlations) with income, prices, urbanization and electrification rate, amongst other drivers (see Mcneil & Letschert 2010, for example). Rather, annual percentage distribution of households generated for each scenario over the model timeline at levels 1, 2 and 4 of the model structure for input to Lagos-LEAP, are based on assumed relationships between the model drivers (independent variables) and relevant subcategories at respective category-levels (dependent variables). These assumed relationships are based on linkages ascribed in literature; and are treated to provide parameter correlations by which annual percentage distribution of households can be generated over the model timeline.

Generating this data to input to LEAP required a number of conditions. Firstly, the scenario drivers were represented by measurable indicators for quantitative treatment, subject to data availability. Secondly, some of the subcategories from the variables outlined in Section 8.2.1 form the dependent variables used to determine parameter correlations; however, the state household surveys — which served as the main source of data for disaggregating the model structure and developing the energy consumption database — date only as far back as 2006, and are therefore insufficient to make projections from 2010. There is also a dearth of time series historical data pertaining to the state level for indicators that can be used to represent the scenario drivers. Therefore, historical data at the national level played a central role in determining the parameter correlations by which dependent variable

projections were generated: i.e. national-level indicators were selected to represent scenario drivers (independent variables), and national-level historical data was used as a proxy or to extrapolate/calibrate state level historical data — as relevant — for some subcategories (dependent variables) during parameter correlation estimations.

The use of national-level indicators for the *independent variables* is relevant, since the external environment is characterised by influences that cut across local, state and national-level drivers. For example, the law enforcement driver selected to describe scenarios is primarily influenced by developments that take place at the national level. Furthermore, Lagos’ role as the central hub of non-oil economic activity in Nigeria means that its economic trends have a major bearing on national trends. While the use of national-level historical data to extrapolate state-level historical data for some of the *dependent variables* introduces the risk of misrepresentation in parameter correlations, there is relevance to this attribution. This is because trends in demographics such as slum population and income at the national level are not dissimilar to those of Lagos; as the state epitomises much of the divisions that best describe Nigeria (see Section 6.2). In addition, because the scenario drivers are based on national-level indicators (independent variables), the state-level trends for dependent variables — some of which are assumed to be similar to national-level trends — will be relatable to the independent variables during parameter correlations. This would not be the case if the scenario drivers were based on state-level indicators.

A detailed treatment of the data used to obtain parameter correlations and the considerations had in their selection can be found in Tables D.3 and D.4 in Appendix D. The indicators and relationships used to determine parameter correlations and generate input data for annual household percentage shares at levels 1, 2 and 4 over the model timeline are outlined under the headings that follow. In some cases, indicators that suitably represent a scenario driver have not been utilised for reasons associated with obtaining parameter correlations. These include; data unavailability, or poor projection suitability of the historical data with the subcategory the driver is related to.

### ***Scenario driver indicators***

**Administrative capacity:** The *regulatory quality* estimate for Nigeria is used to indicate its administrative capacity driver. It is an estimate of “perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development” (Kaufmann et al. 2010, p. 4). The annual score for a country is given in units of a standard normal distribution between -2.5 (lowest) and 2.5 (highest).<sup>3</sup> Another indicator that gives a score on ‘government

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<sup>3</sup>The decision to measure country scores in units of a standard normal distribution was an “innocuous choice” made by the developers of the indicator, to aid their method adopted for combining many sources of data into one aggregate indicator (Kaufmann et al. 2010, p. 9) (see also Kaufmann et al. 1999).

effectiveness’ would also have been a useful indicator of administrative capacity (idib., p. 4); however, it was not used due to the poor suitability (produced nonsensical results) of historical data for the indicator to project future values for the subcategory this driver is assumed to influence (discussion on parameter correlations used to project household percentage share data is found in Section 8.3.3).

**Infrastructure:** Nigeria’s *gross fixed capital formation*, expressed as a percentage of GDP, is used to indicate developments in infrastructure in each scenario. The indicator is a measure of the net increase in fixed capital; such as land improvements, the construction of transportation infrastructure, and buildings (World Bank 2018f).

**Economic transformation and productivity:** Three indicators are used to represent this scenario driver: (i) *manufactures exports*, expressed as a percentage of merchandise exports; (ii) *agriculture value added* measured in 2005 US\$ per worker; and (iii) *Gross Domestic Product (GDP) per capita*, expressed in 2011 international dollars. Manufactures includes commodities such as chemicals, electronics, processed foods, and others.<sup>4</sup> Agricultural value added per worker is a measure of agricultural productivity (World Bank 2018f).

**Law enforcement:** The *rule of law* estimate for Nigeria is used to indicate its law enforcement driver. It is an estimate on “perceptions of the extent to which agents have confidence in and abide by the rules of society” (Kaufmann et al. 2010, p. 4). The annual score for a country is given in units of a standard normal distribution between -2.5 (lowest) and 2.5 (highest).

**Economic formality:** Because historical data on informal employment in Nigeria or Lagos did not exist, this scenario driver is represented by the level of *vulnerable employment*, expressed as a percentage of total employment. Data on the Sub-Saharan Africa average was used as a proxy for Nigeria (ILO 2015).<sup>5</sup> The International Labour Organization (ILO) combine two characteristics of a worker’s status to define ‘vulnerable employment’: own-account workers, and contributing family workers. They consider a sizeable proportion of own-account workers to be an indication of a large agricultural sector and a small formal economy; and class contributing family work as a form of labour that is generally unpaid, in support of family businesses or farming (ILO n.d.).

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<sup>4</sup>Category of manufactures used in this data are defined as commodities under sections 5 to 8 of the Standard International Trade Classification (SITC) (UNCTAD 2017).

<sup>5</sup>Historical data of vulnerable employment in Nigeria, made available by the World Bank following the undertaking of this work, show that the use of the SSA average for this indicator was a reasonable attribution, because annual percentage change — which is the basis of parameter correlations and future household percentage distribution data generation — in the value of the indicator at the continent level are similar to those at the country level. For example, there was an overall fall in vulnerable employment in SSA from 80 % to 77 % between 2000 and 2014, and a similar fall from 82 % to 79 % over the same period in Nigeria (see World Bank 2018g, for Nigeria data).

Both characteristics are considered to present workers with a lower likelihood of formal work arrangements and so the indicator is considered suitable to represent economic formality in this work.

**Domestic purchasing power:** Two indicators are used to represent this scenario driver:

- (i) *Gross National Income (GNI) per capita*, expressed in 2011 international dollars; and
- (ii) the *national price level*, expressed as a ratio of the purchasing power parity conversion factor of GDP to the country's currency market exchange rate (World Bank 2018f). The latter indicator provides an indication on the amount of dollars required to buy one dollar's worth of goods in a given country in comparison to the benchmark country, the United States.

### ***Subcategory indicators at levels 1, 2 and 4 of model structure***

Indicators were needed at category-levels 1, 2 and 4, to which the indicators of the scenario drivers could be related; where their respective time series historical data can be used to generate parameter correlations, which will be used to project annual percentage share of total households at each category-level over the model timeline (projected from 2010 base values of household distribution). As introduced in Section 8.2.1 the dependent variables at levels 1, 2 and 4 refer to the settlement (*urban non-slum, urban slum, and rural*), income (*high, medium, low, and poor*), and energy consumption efficiency (*base and efficient*) categories respectively. Since the total of all shares across all subcategories at a given category-level must equal 100 in every given year, the following decisions were made:

- At level 1 (settlement), annual household percentage distribution data was generated for the *urban (non-slum + slum)* and *slum* subcategories in accordance with changes in related scenario drivers and their respective indicators in each scenario. The annual shares for the *non-slum* subcategory constituted the remainder of the *urban* share less the *slum* share ( $non-slum\ share = urban\ share - slum\ share$ ). The annual shares for the *rural* subcategory constituted the remainder of the total ( $rural\ share = 100 - urban\ share$ ).
- At level 2 (income), the *high* subcategory annual percentage share of households was assumed to remain fixed over the model timeline (5 % in the non-slum settlement, 2 % in the rural settlement, and 0 % in the slum settlement — see Table 8.2). Annual household percentage share data was generated for a combination of the *low + poor* subcategories, and for the *poor* subcategory in accordance with changes in related scenario drivers and their respective indicators in each scenario. The data (both historical and generated) for the two subcategories were treated separately according to

the settlement they were connected to in the preceding level of the model structure.<sup>6</sup> The annual shares for the low subcategory constituted the remainder of the combined *[low + poor]* share less the poor share (*low share = [low + poor] share - poor share*). The annual shares for the *medium* subcategory constituted the remainder of the total (*medium share = 100 - high share + [low + poor] share*).

- At level 4 (energy consumption efficiency), annual household percentage distribution data was generated for the *efficient* subcategory in accordance with changes in related scenario drivers and their respective indicators in each scenario; with the annual share for the base subcategory constituting the remainder of the total (*base share = 100 - efficient share*). A distinction was made between annual household percentage share changes for *efficient* subcategories that are part of branches with the urban (non-slum and slum) subcategory at level 1 and those that are part of branches with the rural subcategory at the same level. These were given separate indicators.

Therefore, (dependent variable) indicators to be related with indicators of the scenario drivers (independent variables) were only needed for the following subcategories:

- (i) Level 1 — urban (non-slum + slum) and slum
- (ii) Level 2 — *[low + poor]* and poor (for each settlement at level 1 of the model structure)
- (iii) Level 4 — efficient-urban and efficient-rural

**Urban:** The *urbanization level* of Lagos, expressed as the percentage share of the state population residing in urban areas, is used to indicate the share of households at this subcategory in accordance with available historical data (UN-Habitat 2013).

**Slum:** The *proportion of urban population living in slum conditions* in Nigeria is used as a proxy-indicator for the slum subcategory in accordance with available historical data (UN-Habitat 2013). This was a relevant attribution because Lagos is one of the foremost urban states in Nigeria. Estimates of the slum population of Lagos and urban-Nigeria in 2010 and 2009 respectively were both circa 63 % (Agbola & Agunbiade 2009, World Bank 2011a, UN-Habitat 2013). In 1995, Lagos was estimated to have almost 70 % of its total population living in slums (World Bank 2006); translating to circa 70 % or just above of its urban population living in slum conditions. Similarly,

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<sup>6</sup>Since the historical data used to determine parameter correlations at this level for the *[low + poor]* and poor subcategories was extrapolated for Lagos (backwards from 2010 figures) using national-level historical data, distinctions were made for each of the two subcategories according to the settlement they branched from. Therefore, the historical data used to determine parameter correlations, and thus generate annual household percentage distribution data from 2011-2043, for *[low + poor]* and poor subcategories differed according to connections to either the urban non-slum, urban slum, or rural settlement subcategories in the preceding level of the model structure.



the proportion of Nigeria's urban population living in slum conditions in 1995 was estimated at 73.5 % (UN-Habitat 2013).

**Low + Poor:** The *relative poverty level* in Nigeria, expressed as the proportion of the population living under \$2 per day (2005 international prices) (World Bank 2018f), was used to extrapolate and calibrate historical data for each [low + poor] indicator across the settlement subcategories. This attribution is relevant due to the similarities in income/poverty trends between Lagos and Nigeria. Although estimates record Lagos to have achieved greater poverty reduction between 2004 and 2010, than reductions experienced at the national level over the same period (World Bank 2015c), the directional trend in the 30 years to 2010 have been similar. In the decade leading up to the mid-to-late 1990s, poverty increased at both the state and national level (World Bank 2006, Falola & Heaton 2008, World Bank 2011a, 2018f); born of the ills of military rule (see Section 6.2.1). Since then there has been a decline in poverty at both levels (World Bank 2015c, 2018f).

**Poor:** The *absolute poverty level* in Nigeria, expressed as the proportion of the population living under \$1.25 per day (2005 international prices) (World Bank 2018f), was used to extrapolate and calibrate historical data for each poor indicator across the settlement subcategories.<sup>7</sup>

**Efficient-urban:** Due to unavailability of time series historical data pertaining to appliance uptake or household consumption levels at state or national scale in Nigeria, the *urban white goods ownership level* in China, expressed as the proportion of urban households that own a refrigerator (Fridley et al. 2013), was used to determine parameter correlations between respective scenario drivers and the efficient-urban consumption efficiency subcategory. For determining parameter correlations at this level only, the historical data on China for respective scenario driver indicators were also utilised (World Bank 2018f). The parameter correlations for China are then applied with respective scenario driver indicator pathways stated in each scenario for Nigeria to generate annual household percentage share input data for this subcategory. The relevance of attributing relationships experienced in China is because the country's records present historical data from the very start of the appliance penetration process (from 1981 when ownership is at or close to 0 %), which is useful for assuming the trajectory of change from base consumption efficiency to efficient consumption efficiency; where the latter starts at 0 % in the base year of the model.

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<sup>7</sup>Historical data on absolute poverty and relative poverty used in parameter correlation were based on the previous UN-prescribed global poverty lines; where absolute poverty had a threshold of \$1.25 (2005 PPP). This is because the data correspond to periods prior to the updated 2015 poverty lines; where absolute poverty has a threshold of \$1.90 (2011 PPP) (Ferreira et al. 2015).

**Efficient–rural:** For the same reasons as the previous subcategory and with the same considerations, the *rural white goods ownership level* in China, expressed as the proportion of rural households that own a washing machine, was used to determine parameter correlations between respective scenario drivers and the efficient–rural consumption efficiency subcategory.<sup>8</sup>

### ***Dependent and independent variable relationships***

As mentioned at the beginning of this section, the relationships attributed between dependent and independent variables selected are not exhaustive, and there are relevant describing factors that have been omitted from the exercise for reasons including data unavailability and limited relevance to driving energy behaviour. The independent variable attributions made for each dependent variable are outlined below, and depicted in Table 8.4.

**Urban (level 1):** The *urban (non-slum + slum)* dependent variable is related to the *manufactures exports* and *agricultural value added* independent variables of the economic transformation and productivity driver. The urban–rural residency shares, and thus access to and behaviour with energy services, is linked with economic opportunity. Growing opportunity for jobs in industry can impact smallholder farming, just as it can be impacted by increased productivity in the agriculture sector (Bradshaw 1987, Gollin et al. 2016).

**Slum (level 1):** The *slum* dependent variable is related to the *regulatory quality estimate*, *gross fixed capital formation*, and *rule of law estimate* independent variables of the administrative capacity, infrastructure, and law enforcement drivers respectively, as well as the *urban* dependent variable above. The use of the urban dependent variable as a describing variable here is to provide consistency across the subcategories of level 1 of the model structure. Urbanization, amongst other factors, is linked to slum proliferation (UN-Habitat 2013). The incidence of people living in slum conditions, and the insecurity and informality of services and transactions it entails, correlate with infrastructure provision such as affordable housing (or lack thereof) (Arimah 2010). The ability or inability of a governing body to effectively plan and regulate urban growth is also understood to be related to the incidence of slums (Fox 2013).

**Low + Poor (level 2):** The *[low + poor]* dependent variable is related to the *GDP per capita*, *rule of law estimate*, *vulnerable employment*, and *GNI per capita* independent variables of the economic transformation and productivity, law enforcement, economic formality, and domestic purchasing power drivers respectively. Economic output and

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<sup>8</sup>The use of washing machine ownership for the rural area instead of the refrigerator ownership adopted for the urban area was due to slightly faster penetration of washing machines in China. The trajectory of refrigerator penetration in rural China over the first 30 years was very slow, which hinders its applicability as a proxy for the model.

national income levels are linked with poverty levels, but due to the prevalence of inequality are not perfect descriptors (UNECA 2013). The presence of better and more jobs, in addition to financial inclusion made possible by strong and flexible contractual enforcement mechanisms, also correlate with the livelihood resources of households and the (energy) services they can afford (Stein et al. 2013, World Bank 2014*b*, 2015*b*).

**Poor (level 2):** The *poor* dependent variable is treated with the same attributions as the *[low + poor]* dependent variable.

**Efficient–urban (level 4):** The *efficient–urban* dependent variable is related to the *GNI per capita* and *national price level* independent variables of the domestic purchasing power driver. The market presence of technologies, which describes competitiveness and shapes household uptake, is linked to the purchasing power of households and average prices of important goods in the economy (Prahalad 2006). Index numbers (first historical data point treated as reference year) of respective historical time series data (and scenario driver projections) were utilised for the independent variables at this level, due to the use of China as a proxy for parameter estimations in this case; whose GNI and national price levels are different to Nigeria’s in the years leading to the base year of the model, and would therefore yield nonsensical predictions of future data for the dependent variable if their absolute figures were used.

**Efficient–rural (level 4):** The *efficient–rural* dependent variable is treated with the same attributions as the *efficient–urban* dependent variable.

**Table 8.4:** Attributed dependent and independent variable relationships for generating annual household percentage distribution input data over model timeline

			SCENARIO DRIVERS											
			Independent Variable	Administrative capacity	Infrastructure	Economic transformation and productivity			Law enforcement	Economic formality	Domestic purchasing power			
MODEL STRUCTURE LEVEL	Subcategories	Dependent Variable	Indicator	Regulatory quality estimate	Gross fixed capital formation (% of GDP)	Manufactures exports (% of merchandise exports)	Agriculture value added (2005 US\$ per worker)	GDP per capita, PPP (2011 \$)	Rule of law estimate	Vulnerable employment (% share)	GNI per capita, PPP (2011 \$)	National Price level (ratio of PPP conversion factor of GDP to market exchange rate)	Urbanization level (% total pop)	
SETTLEMENT (LEVEL 1)		Urban population	Urbanization level (% total pop)	X X										
	Slum	Slum population	Proportion of urban population in slum (% urban pop)	X	X	X							X	
	Non-slum	Remainder or urban less slum	N/A											
	Rural	remainder of 100 less urban	N/A											
INCOME (LEVEL 2)	High	Assumed	N/A											
	Medium	Remainder of 100 less [low + poor]	N/A											
		[Low + Poor]	Proportion of population living under \$2 per day	X					X	X	X			
	Low	Remainder of [low + poor] less poor	N/A											
	Poor	Poor population	Proportion of population living under \$1.25 per day	X					X	X	X			
RETICULATED ELECTRICITY AVAILABILITY (LEVEL 3)	Base	Assumed	N/A											
	High	Assumed	N/A											
ENERGY CONSUMPTION EFFICIENCY (LEVEL 4)	Base (urban branches)	Remainder of 100 less efficient-urban	N/A											
	Base (rural branches)	Remainder of 100 less efficient-rural	N/A											
	Efficient (urban branches)	Efficient-urban	Urban white goods ownership (% urban pop)									X	X	
	Efficient (rural branches)	Efficient-rural	Rural white goods ownership (% rural pop)									X	X	

### 8.3.3 Parameter correlation estimation and annual household percentage distribution data generation method

The parameter correlations between the attributed dependent and independent variable relationships were estimated using regression analysis. The generalized linear model (GLM) developed by Nelder & Wedderburn (1972) is the theoretical model used to explain the link between the dependent and independent variables. This section will provide details on regression analysis and the use of GLM in this work; and present the parameter correlation estimations of related dependent and independent variables, and the statistical significance of their estimates. Section 8.4.2 will present the predicted annual household percentage distribution data (dependent variables) for each scenario explored (according to their stated independent variable pathways), which served as inputs to the Lagos-LEAP model. The statistical software package Stata 12 was used for all estimations and predictions.<sup>9</sup>

#### *The generalized linear regression model (GLM)*

Regression analysis is a statistical technique for estimating the parameter coefficients indicating the relationship between a dependent variable and one or more independent (describing) variables (Gujarati 2004). It is a widely used tool in a range of fields including, but not limited to, economics and medical research. Though its numerous methods and approaches remain an active field of research, this section aims to introduce its method of application as it pertains to this research; starting with an acknowledgement of its most common form — the classic linear regression model.

$$Y_i = \alpha + \beta_1 X_{i1} + \cdots + \beta_k X_{ik} + \varepsilon_i \quad (8.1)$$

where, for a set of sample observations, the relationship between the dependent variable  $Y_i$  and the  $k$ -vector of descriptive variable  $X_i$  is denoted by the latter's partial effect  $\beta_k$ , with  $\varepsilon_i$  describing any measurement errors.

The classic linear regression model — which utilises the ordinary least squares technique in its fitting procedure (see Chapter 5 in Fox 2016) — is predicated on a number of assumptions; one of which is a linear relationship between variables. This assumption does not hold for the variable relationships being explored in this work, as the dependent variables come from an exponential family distribution; specifically the binomial distribution (Fox 2016). The data for the dependent variables being analysed and estimated take the form of proportions and are therefore bounded between and including 0 and 1 (or 0 and 100 %). The utilisation of a linear regression model for this form of data will yield incorrect results,

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<sup>9</sup>Stata is a data analysis and statistical software package with a wide range of capabilities, including data management, statistical analysis and regression modelling, and used in fields such as economics and medical research (StataCorp 2018).

particularly for extreme values of the independent variables (which can lead to predictions that are outside the bounds of the dependent variable) (Baum 2008). There exist a range of alternative functional forms and estimation techniques to the classic linear regression model, which allow modelling of data from the exponential family (see Gujarati 2004). However, an appropriate model for the data used in this work, considering the bounded nature of the dependent variables; is the logit transformation of a *generalized linear model* (GLM).

GLM has been widely used for statistical data analysis in a range of fields; particularly in finance, healthcare, and medical research (see de Souza et al. 2015, p. 22 for examples). One of its principle features is its ability to incorporate a range of link functions which transform the expected dependent variable according to its distribution. The *logit* transformation of GLM is typically suitable to applications where outcomes are described in terms of the odds ratios, such as in clinical research (de Souza et al. 2015), making it suitable to data of the binomial distribution when the dependent variable is continuous (0 to 1); as is the case in this work. As opposed to the use of an ordinary least squares method for fitting, as is found with the classic linear regression model, GLM's original estimation algorithm is based on the maximum likelihood estimation (Nelder & Wedderburn 1972).<sup>10</sup>

The equations below present the functional form of the generalised linear model (GLM) with a logit link function (Equations 8.3 and 8.5); which was used to identify maximum likelihood historical data correlations for the indicator relationships attributed in Table 8.4. The GLM's general form consists of the use of a linear predictor (Equation 8.2), transformed using a link function (Equation 8.4); which in this case is to satisfy the distribution of a dependent variable belonging to an exponential family (Fox 2016).

$$g(\mu_i) = \eta_i = \alpha + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik} \quad (8.2)$$

$$E(Y_i) \equiv \mu_i = g^{-1}(\eta_i) \quad (8.3)$$

where  $\eta_i$  represents the linear predictor for the  $i$ th of  $n$  independently sampled observations with given explanatory variables; a dependent variable  $Y_i$  belonging to a specified distribution, which for all dependent variables in Lagos-LEAP is the binomial family, as all values can lie between 0 and 1; and the inverse of the link function  $g(\cdot)$  providing an appropriate transformation from the linear predictor  $\eta_i$ , to the conditional mean  $\mu_i$  — which took the

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<sup>10</sup>The maximum likelihood estimation method “consists in estimating the unknown parameters in such a manner that the probability of observing the given  $Y$ 's is as high (or maximum) as possible” (Gujarati 2004, p. 115). Bayesian statistical analysis has also been adopted for the GLM function to estimate Bayesian logistic models (de Souza et al. 2015), but the maximum likelihood estimation approach to GLM data fitting is the default approach for Stata (StataCorp 2013).

form of the logit link function:

$$g(\mu_i) = \eta_i = \ln \frac{\mu_i}{1 - \mu_i} \quad (8.4)$$

inversed to produce a mean function;

$$E(Y_i) = \mu_i = \frac{1}{1 + e^{-\eta_i}} \quad (8.5)$$

### ***Regression estimations***

Using Stata 12, the maximum likelihood estimation of the GLM regression with a logit link function relies on iterative reweighted least-squares optimization of the log likelihood to provide outputs on: the maximum likelihood estimate of the parameter coefficients for each independent variable, their associated standard errors, the approximate confidence intervals around the estimated coefficients at the 95 % level, and a  $p$ -value for each independent variable computed from the Wald test, amongst others (Hardin & Hilbe 2013).<sup>11</sup> The tables below provide the parameter estimations of the regression models conducted for indicators at levels 1, 2, and 4, and their corresponding levels of statistical significance.

A very small number of the regressors (independent variables) were not significant at the 1 %, 5 %, or 10 % levels; suggesting that they may have no association with their respective dependent variable. However, these variables were not rejected in response to this, as the levels at which any of the independent variables are said to be significant are still susceptible to type I and type II errors, for reasons not always known (see Gujarati 2004).<sup>12</sup> So given that the selected scenario drivers (independent variables) used in this work were limited to those relevant to the scope of the work (external environment factors influencing household energy behaviour), as mentioned in Section 8.3, misspecification errors are possible by reason of relevant descriptive variables that have been omitted.<sup>13</sup> It was more useful rather, to test the validity of the regression estimates by comparing predicted values with actual (real) values.

Among Stata's post-estimation commands for a range of functions including hypothesis testing, it allows for the prediction of the dependent variable using the estimated regressors, for the same historical period used to estimate the parameters; essentially serving as a test

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<sup>11</sup>The Wald test determines how statistically significant an independent variable is, using the parameter coefficient and its asymptotic standard error to test the null hypothesis  $H_0 : \beta_j = \beta_j^{(0)}$  — which is to test that an individual regression coefficient is zero (Fox 2016).

<sup>12</sup>A type I error is rejecting a null hypothesis that is true, while conversely a type II error is failing to reject a hypothesis that is false (Gujarati 2004).

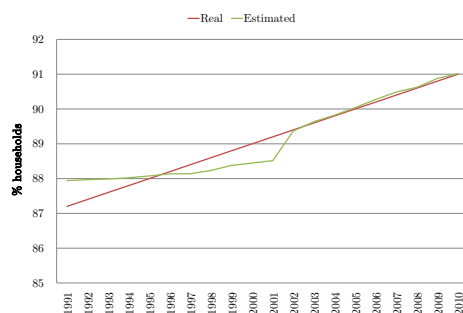
<sup>13</sup>Misspecification errors include those that stem from the use of a theoretical model whose functional form is not suited to the variables in question, or when descriptive variables that should be included are omitted and vice-versa (Gujarati 2004), and can lead to type I or type II errors (Litière et al. 2007, Figueiredo Filho et al. 2013).

on its accuracy and hence its usefulness to project future values.<sup>14</sup> This (predict) function was also then used with user-defined independent variable pathways for the forward-looking scenario timelines, to estimate the annual household percentage shares till the model end year; which served as input data to Lagos-LEAP.

Most of the regression models predicted annual values for the dependent variables with a percentage difference less than 1, when compared to their corresponding real data. This suggests the models estimated reasonable parameter correlations, which can be used to project future values. The only instance where the percentage difference for a few data points were larger, was with white goods ownership at level 4. Nevertheless, most of the annual data points for estimates at this level did not vary too far from real values. These predicted and real data comparisons for the regressions conducted at each level of the model structure are presented in the figures that follow.

### Level 1 regression models

**Figure 8.3:** Variation between real and estimated urbanization rate



**Table 8.5:** Regression estimates for urbanization rate

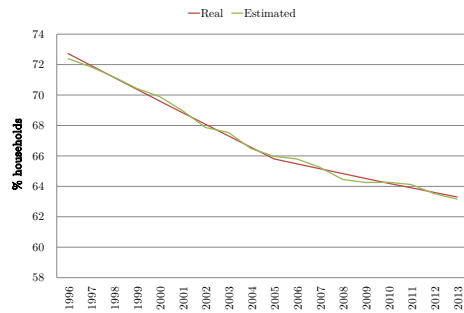
	$\beta$ coefficient	95% Conf Interval	
<b>Manufactures Exports</b>	-0.0028503****	-0.01118	0.005475
<b>Agriculture value added</b>	0.0001161*	0.000103	0.00013

\*Significant at 1 % level  
\*\*\*\*Significant at 51 % level

<sup>14</sup>A more stringent test of the regression results would be between predicted and real values on annual data not used in the estimation process (measure of forecasting ability). But at the time of analysis, all available annual data points were used (in a few cases no more than 3 years of the most recent annual data points were omitted) to predict data for which there were no real values (particularly because the model sought predicted values beyond the present day i.e. till 2043). Any attempt to reduce the time series data used to estimate parameter correlations in order to measure forecasting ability, would have also decreased the power of the data used; and thus, diminished the strength, and test, of the full time series historical data adopted in regressions.



**Figure 8.4:** Variation between real and estimation slum share of population



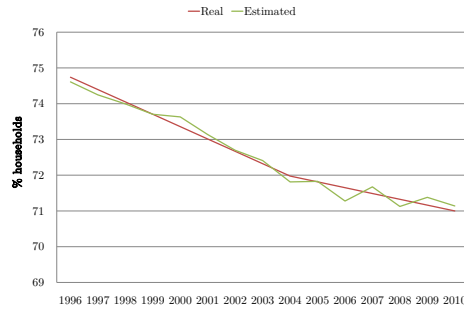
**Table 8.6:** Regression estimates for slum share of population

	$\beta$ coefficient	95% Conf Interval	
<b>Regulatory quality</b>	0.0362409**	0.000125	0.072356
<b>Gross fixed capital formation</b>	0.0066146*	0.004685	0.008544
<b>Rule of law</b>	0.0347408****	-0.02088	0.090361
<b>Urbanization rate</b>	-0.1599712*	-0.16734	-0.1526

\*Significant at 1 % level  
 \*\*Significant at 5 % level  
 \*\*\*\*Significant at 23 % level

## Level 2 regression models

**Figure 8.5:** Variation between real and estimated share of non-slum population living under \$2 per day

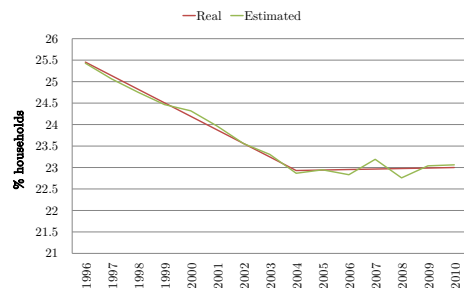


**Table 8.7:** Regression estimates for non-slum population living under \$2 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.0843358*	0.044608	0.1240637
<b>GNI</b>	-0.0000884*	-0.00013	-0.0000458
<b>GDP</b>	0.0001109*	0.0000561	0.0001657
<b>Vulnerable employment</b>	0.0657694*	0.050416	0.0811226

\*Significant at 1 % level

**Figure 8.6:** Variation between real and estimated share of non-slum population living under \$1.25 per day

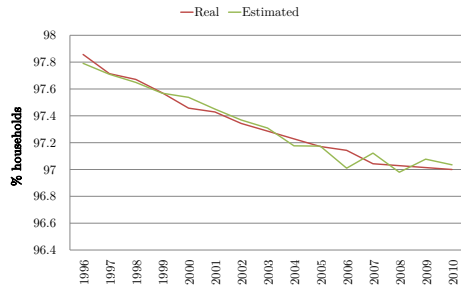


**Table 8.8:** Regression estimates for non-slum population living under \$1.25 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.086545*	0.0598538	0.1132361
<b>GNI</b>	-0.000045*	-0.0000649	-0.0000252
<b>GDP</b>	0.0000883*	0.0000638	0.0001127
<b>Vulnerable employment</b>	0.0733585*	0.0658718	0.0808382

\*Significant at 1 % level

**Figure 8.7:** Variation between real and estimated share of slum population living under \$2 per day



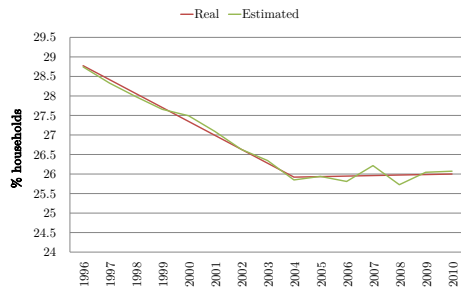
**Table 8.9:** Regression estimates for slum population living under \$2 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.1088966**	0.013443	0.2043507
<b>GNI</b>	-0.0001564*	-0.00026	-0.0000504
<b>GDP</b>	0.0002199*	0.0000753	0.0003645
<b>Vulnerable employment</b>	0.1308461*	0.088856	0.1728364

\*Significant at 1 % level

\*\*Significant at 5 % level

**Figure 8.8:** Variation between real and estimated share of slum population living under \$1.25 per day

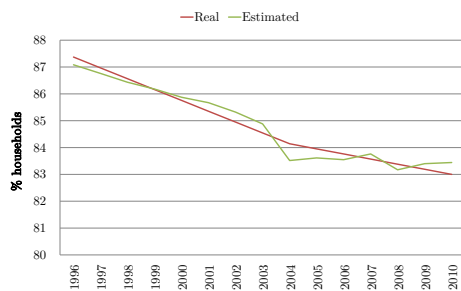


**Table 8.10:** Regression estimates for slum population living under \$1.25 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.0902793*	0.0623819	0.1181768
<b>GNI</b>	-0.0000471*	-0.0000678	-0.0000263
<b>GDP</b>	0.0000923*	0.0000667	0.0001178
<b>Vulnerable employment</b>	0.076562*	0.0687125	0.0844114

\*Significant at 1 % level

**Figure 8.9:** Variation between real and estimated share of rural population living under \$2 per day

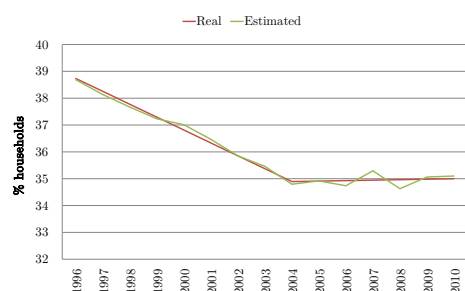


**Table 8.11:** Regression estimates for rural population living under \$2 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.1585136*	0.083632	0.2333952
<b>GNI</b>	-0.0001629*	-0.00024	-0.0000838
<b>GDP</b>	0.0002092*	0.000106	0.0003127
<b>Vulnerable employment</b>	0.1240548*	0.093897	0.1542128

\*Significant at 1 % level

**Figure 8.10:** Variation between real and estimated share of rural population living under \$1.25 per day



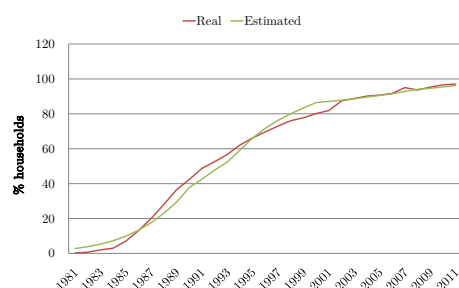
**Table 8.12:** Regression estimates for rural population living under \$1.25 per day

	$\beta$ coefficient	95% Conf Interval	
<b>Rule of law</b>	0.103707*	0.071435	0.135979
<b>GNI</b>	-0.0000545*	-0.0000786	-0.0000304
<b>GDP</b>	0.0001068*	0.000077	0.0001365
<b>Vulnerable employment</b>	0.0881202*	0.0789208	0.0973197

\*Significant at 1 % level

#### Level 4 regression models

**Figure 8.11:** Variation between real and estimated refrigerator ownership in urban China

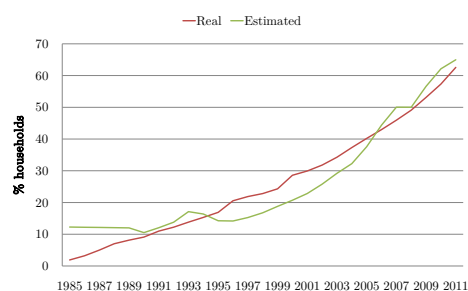


**Table 8.13:** Regression estimates for refrigerator ownership in urban China

	$\beta$ coefficient	95% Conf Interval	
<b>GNI (index)</b>	0.4977242*	0.274582	0.720867
<b>National price level (index)</b>	3.336709****	-1.53309	8.206505

\*Significant at 1 % level  
\*\*\*\*Significant at 18 % level

**Figure 8.12:** Variation between real and estimated washing machine ownership in rural China



**Table 8.14:** Regression estimates for washing machine ownership in rural China

	$\beta$ coefficient	95% Conf Interval	
<b>GNI (index)</b>	0.3663028*	0.272818	0.459788
<b>National price level (index)</b>	-1.582523*	-2.66211	-0.50293

\*Significant at 1 % level

## 8.4 Scenarios

Section 5.4.3 introduced the scenarios explored in Lagos-LEAP, and highlighted their purpose of providing consistent storylines about social, institutional and economic development in Lagos and Nigeria. Therefore, the scenarios explored and their inclusion is not with the aim of identifying the preferred option to be selected — since beneficial scenarios will be evident from their narratives and driver pathways — but rather to aid consistency in the stated pathways of model drivers. Consistency is desired because the scenario drivers describe a particular pathway in the external environment of Lagos and Nigeria, and such external characteristics interact and are shaped by one another.

For example, a region's economic productivity is influenced by infrastructure provision and is related to the level of informality in the economy (UN-Habitat 2013); similarly, the ability to enforce the rule of law and effective governance are related to the administrative capabilities of public institutions (Tankha 2009).

Therefore, there is a risk of stating driver pathways for a particular scenario that are inconsistent and unhelpful to the insights possible from the model; but basing scenarios on a theme that shapes the boundaries and limits of drivers in that scenario is a useful way of facilitating consistency. Nevertheless, perfect consistency is not possible, nor is there any certainty in the pathways drivers can or should take relative to one another, as country and city experiences have shown (see Gollin et al. 2016, for example of urbanization with and without industrialization in some developing countries). What is important, is that the modelling results are not analysed according to the assumed characteristics of scenarios — such as stated influence of public or private action on scenario drivers — but that revelations about the nature of energy consumption over the model timeline inform considerations regarding energy access policy and strategy approaches. For example, analysing what the observed energy service transitions in any scenario, or across scenarios, tell us about potential outcomes when considering a particular policy approach (such as subsidy support).

A brief narrative of each scenario is given in the next section, before the pathways ascribed to the indicators of their drivers are illustrated in Section 8.4.2. The final annual household percentage distribution data inputs to Lagos-LEAP from 2010–2043, for each scenario, are depicted in Section 8.4.3.

### 8.4.1 The scenarios





































Lagos-LEAP models a Reference scenario (REF) — that assumes steady continuity in current development trends and accounts for behaviours of the past — and three alternative scenarios. The themes of the alternative scenarios draw from ongoing discussions around the role of the public and the private sector in energy access activities and wider development (see Chapter 3). Two scenarios adopt pathways of growth driven largely by either one of

these agents of change: the Private Sector scenario (PRI); and the State scenario (STA) — both of which showcase the benefits and ills of an over-reliance on either one of the two institutional sectors. The former scenario represents quick but non-pervasive gains, and limited development in public capacity-related drivers. The latter represents slow progress in development and a burdened state, but relatively higher progress in long-term domestic capacity building. A final scenario ascribes the developmental benefits of both public and private action to facilitate polycentrism and encourage higher gains in medium to long term inclusive development. The state provides an environment for private involvement, and leadership to aid relative gains across the range of drivers that describe the scenarios. None of these scenarios, including the reference scenario, are forecasts of the country's/state's external environment.

### 8.4.2 Scenario driver and indicator pathways

The approach adopted to ascribing driver-indicator pathways in each scenario involved the use of value judgements informed by trends observed in other economies including Brazil, China, South Korea, South Africa, and Morocco. This approach helped minimise the risk of contradictions within a scenario and impractical driver-pathways, by providing limits of change that are in accordance with the experiences of regions that have previously held driver-indicator levels that are similar to Nigeria's in the base year of the model. There is precedent to this approach of using value judgements (see Islas et al. 2007, Limmeechokchai & Chawana 2007, Merven et al. 2010) and drawing on the historical experiences of other countries (see Islas et al. 2007) in the scenario driver pathway attribution. The value judgements informed by historical experiences of other countries included differences across scenarios in peaks, troughs and speed of growth at different stages of the model timeline. The relative pathways for the scenario driver-indicators in each scenario is depicted in Table 8.15.

**Table 8.15:** Lagos-LEAP scenario driver-indicator pathways

SCENARIO DRIVER	Administrative capacity	Infrastructure	Economic transformation and productivity			Law enforcement	Economic formality	Domestic purchasing power	
INDICATOR	Regulatory quality estimate	Gross fixed capital formation (% of GDP)	Manufactures exports (% of merchandise exports)	Agriculture value added (2005 US\$ per worker)	GDP per capita, PPP (2011 \$)	Rule of law estimate	Vulnerable employment (% share)	GNI per capita, PPP (2011 \$)	National Price level (ratio of PPP conversion factor of GDP to market exchange rate)
REF									
PRI									
STA									
HYB									

### 8.4.3 Annual estimated household percentage distribution, model inputs (2011–2043)

As indicated in Table 8.1 and discussed in Section 8.3, the data inputs for annual household percentage shares across the model structure till the end year (2011–2043) were all exogenously estimated aside from levels 0 and 3, which respectively have assumptions made about the total population (level 0) and the share of households that are engaging with *base* or *high* subcategories (see Table 8.3) of hourly reticulated electricity availability according to their settlement (level 3). The assumptions made about percentage households distribution at these levels are the same for all scenarios. For level 0, it is assumed that Lagos state’s population growth follows the UN projected growth rate (2 %) for the state between the base year 2010 and 2025 (UN-Habitat 2013). Following this there is a steady decline in the rate of population growth in the state every five years till 2035; after which, the state population grows at 1 % till the model end year. While the characteristics of the various scenarios can have an impact on the nature of population growth in the state (for example, the nature of economic transformations can have an impact on immigration), scenario-differences in the number of households in the state would provide no impact on relative changes in energy behaviour, as the energy consumption database does not account for differences at level 0, and therefore would be of no use in the analysis of model outcomes. It was therefore useful to keep this variable consistent across all scenarios.

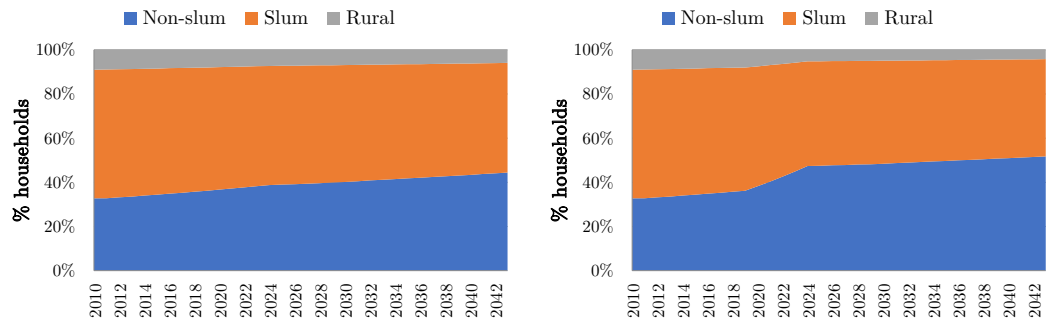
For level 3, the distribution of households that shift to the *high* subcategory for each branch — which represents receipt of more hours of reticulated electricity per day — is also assumed to be the same across all scenarios. As mentioned in Section 8.2.2, in the base year 100 % of households in each settlement are assumed to receive their respective base subcategory provisions of hourly reticulated electricity availability. The model assumes logistic growth in the percentage of households engaging with the high subcategory in each settlement; ending with 2043 household percentage shares of 98.5 % for the non-slum settlement, 68.5 % for the slum settlement, and 59.2 % for the rural settlement in each scenario. These distinctions aimed to capture how urban areas, on average, are the first beneficiaries in stability of networked electricity provision ahead of rural areas (Practical Action 2016). Like population at level 0, reticulated electricity availability can also be impacted by the characteristics of each scenario and modelled with estimated differences accordingly; just as the other levels (1, 2 and 4) were treated. Given the importance of the level 3 subcategories on energy behaviour and thus, the energy outcomes of the model, it was decided that its annual household percentage distributions should be controlled by the above assumptions; and further analysed with variations in the household percentage distribution shifts from base to high subcategories over the model timeline, to see what other insights can be gleaned

(see Section 8.6). The annual household percentage distribution data generated for levels 1, 2 and 4 to input to Lagos-LEAP are presented in the figures that follow.

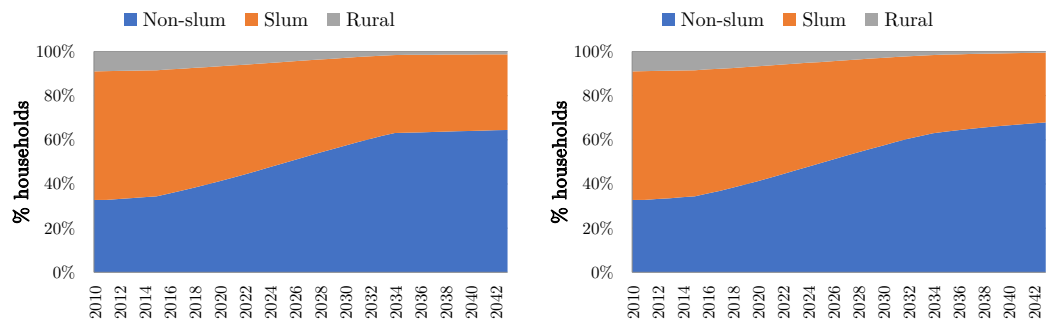
### ***Settlement: Level 1***

**Figure 8.13:** Lagos-LEAP inputs for annual settlement subcategory distribution of households for all scenarios

- (a) Settlement subcategory distribution of households (REF) (b) Settlement subcategory distribution of households (PRI)



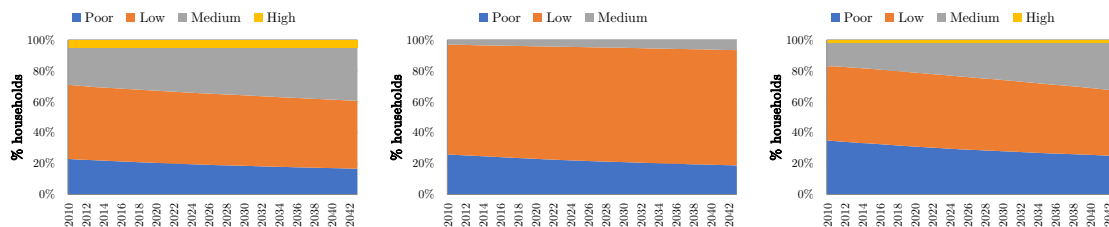
- (c) Settlement subcategory distribution of households (STA) (d) Settlement subcategory distribution of households (HYB)



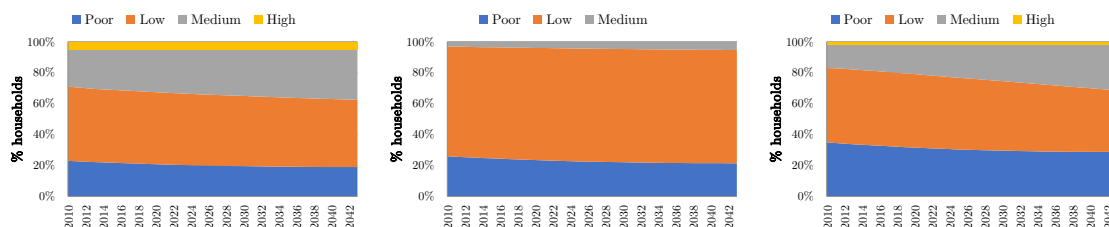
## Income distribution: Level 2

**Figure 8.14:** Lagos-LEAP inputs for annual income subcategory distribution of households for all scenarios

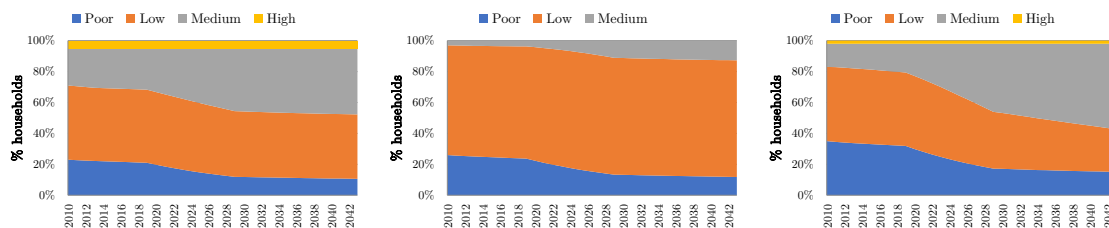
- (a) Non-slum income subcategory distribution of households (REF) (b) Slum income subcategory distribution of households (REF) (c) Rural income subcategory distribution of households (REF)



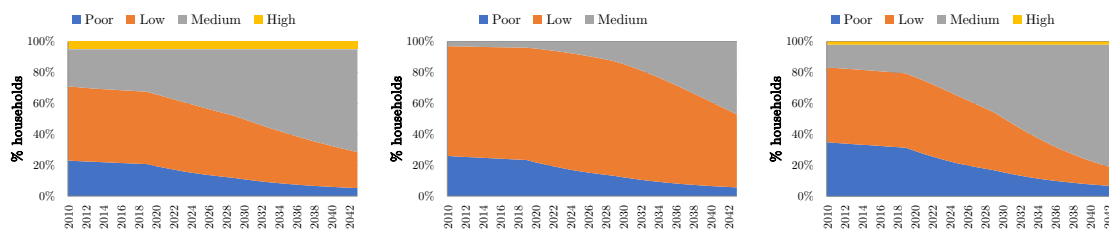
- (d) Non-slum income subcategory distribution of households (PRI) (e) Slum income subcategory distribution of households (PRI) (f) Rural income subcategory distribution of households (PRI)



- (g) Non-slum income subcategory distribution of households (STA) (h) Slum income subcategory distribution of households (STA) (i) Rural income subcategory distribution of households (STA)



- (j) Non-slum income subcategory distribution of households (HYB) (k) Slum income subcategory distribution of households (HYB) (l) Rural income subcategory distribution of households (HYB)

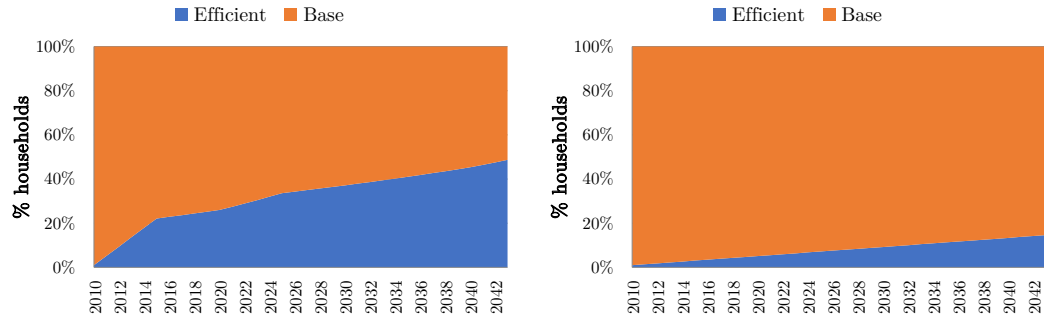


## Energy consumption efficiency: Level 4

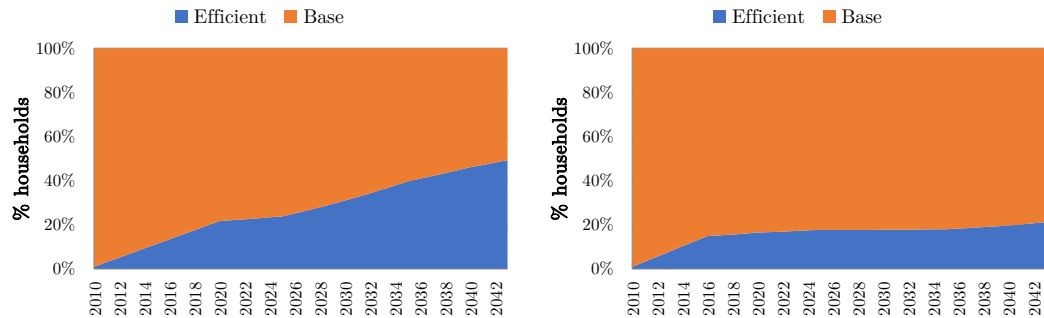


**Figure 8.15:** Lagos-LEAP inputs for annual consumption efficiency subcategory distribution of households for all scenarios

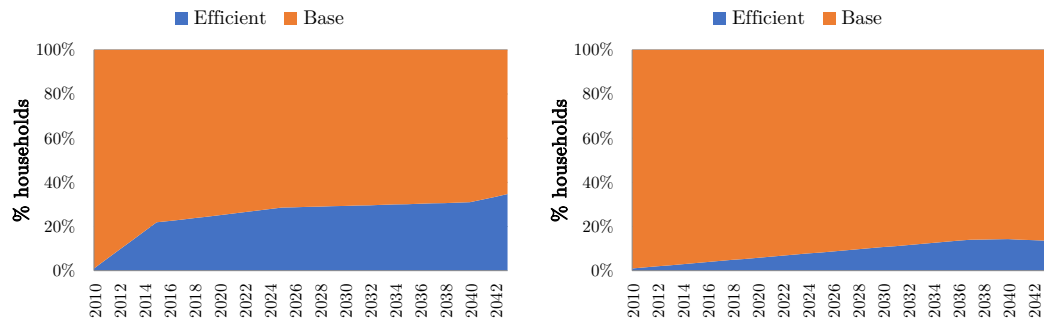
- (a) Consumption efficiency subcategory distribution of urban households (REF) (b) Consumption efficiency subcategory distribution of rural households (REF)



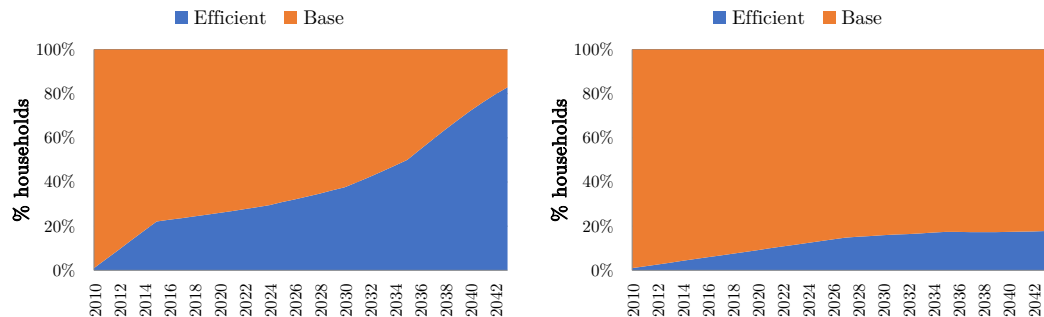
- (c) Consumption efficiency subcategory distribution of urban households (REF) (PRI) (d) Consumption efficiency subcategory distribution of rural households (PRI)



- (e) Consumption efficiency subcategory distribution of urban households (REF) (STA) (f) Consumption efficiency subcategory distribution of rural households (STA)



- (g) Consumption efficiency subcategory distribution of urban households (REF) (HYB) (h) Consumption efficiency subcategory distribution of rural households (HYB)



## 8.5 Lagos–LEAP limitations

The main limitation of the Lagos–LEAP model is the responsiveness of the model’s output to the energy consumption database developed. The nature of the household energy transitions observed for the state will depend on the profiles given to the 44 energy consumption possibilities. As shifts take place across the various profiles, any important profiles excluded from the database or misrepresentations of profiles, could bring forth results and insights that can mislead policy decision-making. While this database was developed using information from a wide range of sources to aid data availability, calibrate, and cross-check data, there is room for stronger secondary data; particularly on information concerning the nature of energy stacking across key demographics. This is an area that is important to strengthen across the developing world when supporting energy access decision-making. The approach used to obtain the annual household percentage distribution inputs does not harm the model’s rigour; because even though the attributed driver–relationships and estimated parameters are not comprehensive, they aid the provision of a range of scenario possibilities from which insights can be drawn — which was their main purpose. While there was limited aggregate energy information by which this bottom-up model could be validated, the focus of analysis on relative differences as opposed to absolute figures means that consistency across the model and scenarios is the most important attribute; and this was achieved by Lagos–LEAP’s reliance on a single energy consumption database, and the same driver relationships and parameter correlations in all scenarios. It is intended that this approach to energy demand modelling, be used in *support* of other energy demand modelling methodologies and energy system models to provide alternative insights on the possible impacts of energy access policy and strategy, for more informed decision-making.

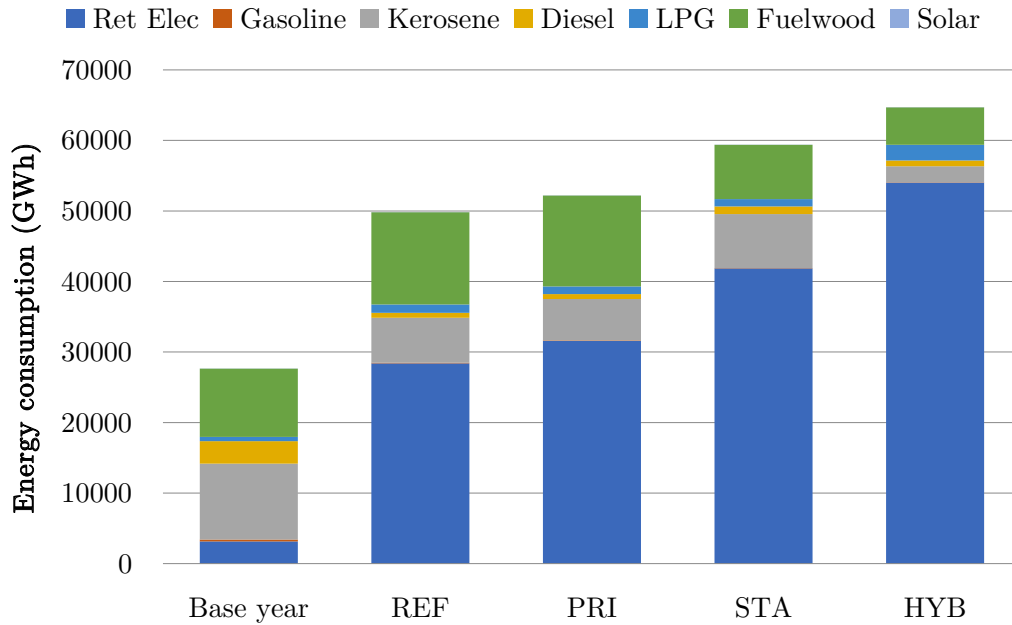
## 8.6 Results

### ***Overall fuel transitions***

Figure 8.16 presents state residential energy consumption by fuel in the end year of all scenarios relative to the base year 2010. In accordance with the scenario pathways, the HYB scenario sees the greatest increase in energy consumption due to greater energy service availability and affordability for households in the state, by virtue of favourable developments in the organisation of daily life captured at the various levels of the model structure. The increased use of reticulated electricity in HYB compared to other scenarios is a result of higher demand for electricity from increased development (see Section 8.4.1). The characteristics of other scenarios also result from these prespecified driver pathways. However as previously stated, examining the results from the perspective of driver influences is not the focus of output from this work, but rather to identify the opportunities for facilitating or

avoiding the energy service transitions observed.

**Figure 8.16:** Residential fuel consumption in 2043 relative to base year



Note: 'Ret Elec' represents reticulated electricity.

The assumed percentage growth in households receiving increased hours of electricity — the same for all scenarios — resulted in electricity constituting the largest share of secondary fuel consumption in all cases, after holding a very limited share of the secondary fuel mix in 2010. It is therefore useful for discussions to consider what further insights can be revealed with varied assumptions for annual household percentage distribution change at this level of the model structure (level 3). As Table 8.16 illustrates, discussions will consider transition outcomes when a *lower* share of households in each settlement receive higher hourly availability of networked electricity by the end year of the model (Low\_RetE scenario); that is, only 20.5 % of Lagos-LEAP households transition from the base subcategory to the high subcategory of hourly reticulated electricity supply at level 3 of the model structure by 2043. It will also consider the *higher* alternative to the initial assumption (High\_RetE scenario); where virtually all households (98.7%) transition to the respective high subcategory at level 3, for each settlement, by the end year of the model. The former in particular, is chosen such that the nature of household energy transitions can be observed under minimal influence from reticulated electricity services. It is useful to reiterate that *reticulated electricity* refers to all forms of networked electricity provision serving multiple

houses; both services from grid and mini-grid.<sup>15</sup>

**Table 8.16:** Share of households across settlement subcategories receiving respective levels of High-subcategory reticulated electricity in model end year 2043

		Non-slum	Slum	Rural
	Original % shares	98.5	68.5	59.2
<b>Variations</b>	Low % shares	20.5	20.5	20.5
	High % shares	98.7	98.7	98.7

*Note:* Above values are the same for all alternative scenarios (PRI, STA and HYB). Variants not modelled for REF. All scenarios, including REF, originally modelled with ‘original percentage shares’ indicated above.

Figure 8.17 shows differences in household fuel demand in Lagos with the ‘Low’ and ‘High’ variants of reticulated electricity availability for the model scenarios by 2043, together with the original base and REF cases, for the purpose of contrast.

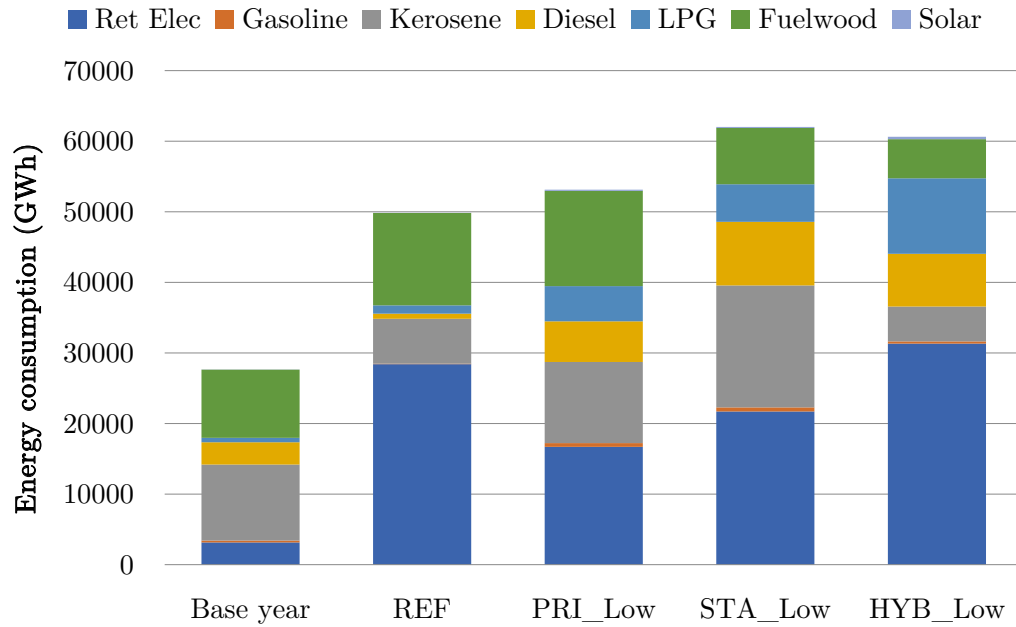
The change in fuel consumption by 2043 in Figure 8.17b is similar to the original model results in Figure 8.16. For Figure 8.17a however, there is a distinct increase in reliance on traditional/transitional fuels; particularly in the STA\_Low scenario where gasoline, diesel, kerosene, and fuelwood consumption constitute 56 % of total fuel demand in 2043.<sup>16</sup> The need for greater levels of private generation does not only result in higher diesel consumption, but also impacts other fuels due to the operational limitations of private generation relative to reticulated electricity (increased cost per hour of electricity supply); necessitating limited use and increased energy stacking. Fuelwood consumption looks relatively unaffected by the hourly availability of reticulated electricity. At first glance, the above results point to the advantage of consistent electricity access for displacing traditional and transitional energy services, when access to the energy carrier and relevant conversion technologies are designed such that they can cater to a wide range of household energy service needs. A look at the cooking energy transitions observed in the scenarios can provide further insight into some of the developments found in the Low\_RetE scenarios for fuels such as LPG and kerosene.

<sup>15</sup>Does not include shared electricity generation by tenants of a particular building or compound. This is considered as private generation.

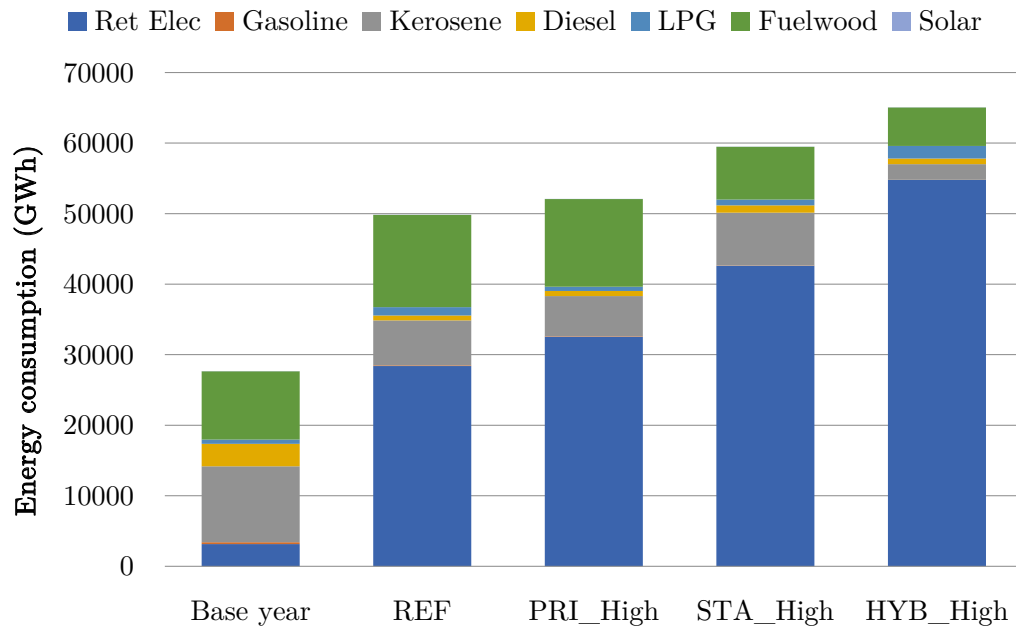
<sup>16</sup>It is useful to remember that although all scenarios receive the same household shares for High\_RetE availability over the model timeline in the level-3 variants (see Table 8.16), the makeup of each scenario over the model timeline as regards the distribution of households across settlements differs (see Figure 8.13). Given that each settlement category received varying hours for both base and high\_RetE (see Table 8.3), the resulting nature of RetE availability in each scenario is different — which therefore impacts fuel demand, as observed in Figure 8.17.

**Figure 8.17:** Energy consumption by fuel in 2043 for Level 3 variations

(a) Fuel consumption in model end year for LOW\_RetE across scenarios compared to base year and REF



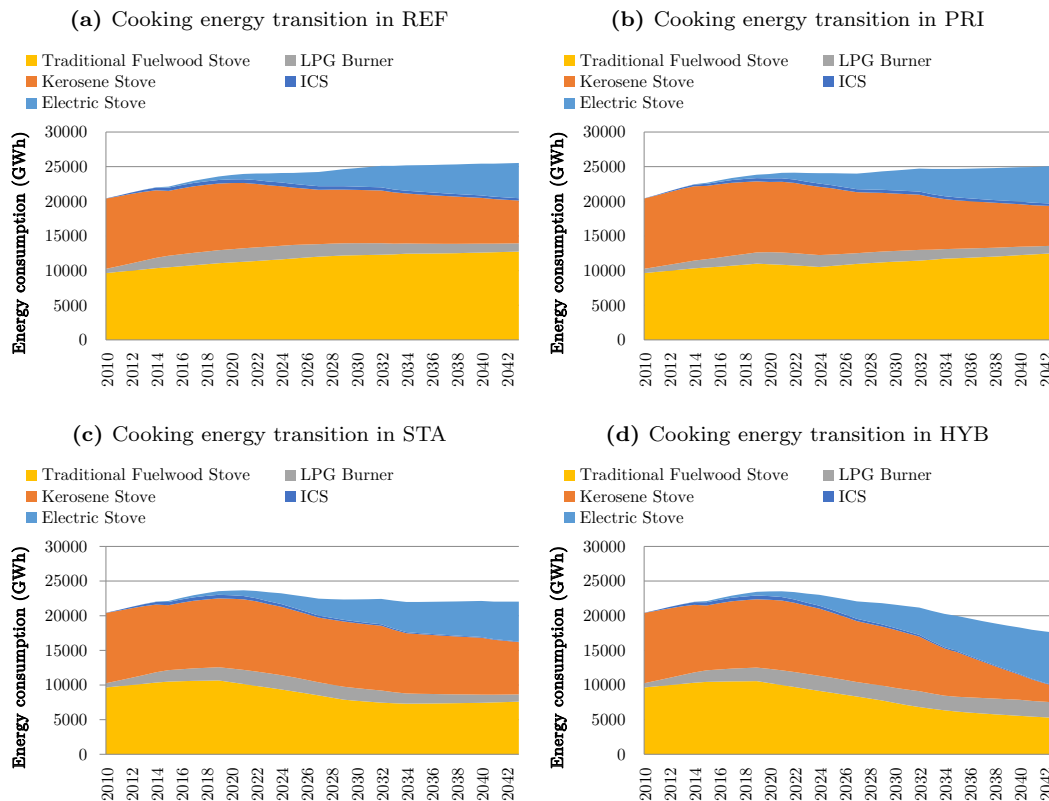
(b) Fuel consumption in model end year for HIGH\_RetE across scenarios compared to base year and REF



## Cooking energy transitions

Figure 8.18 presents the energy transitions observed for the cooking energy service according to the fuel–technology combinations used. The greatest disparity between the modelled scenarios is in HYB; where increased use of efficient (modern) energy services, in the form of the electric and LPG cookstoves, relative to the kerosene and fuelwood cookstoves led to a 14% decrease in overall consumption compared to 2010. But the resulting transitions present some interesting insights.

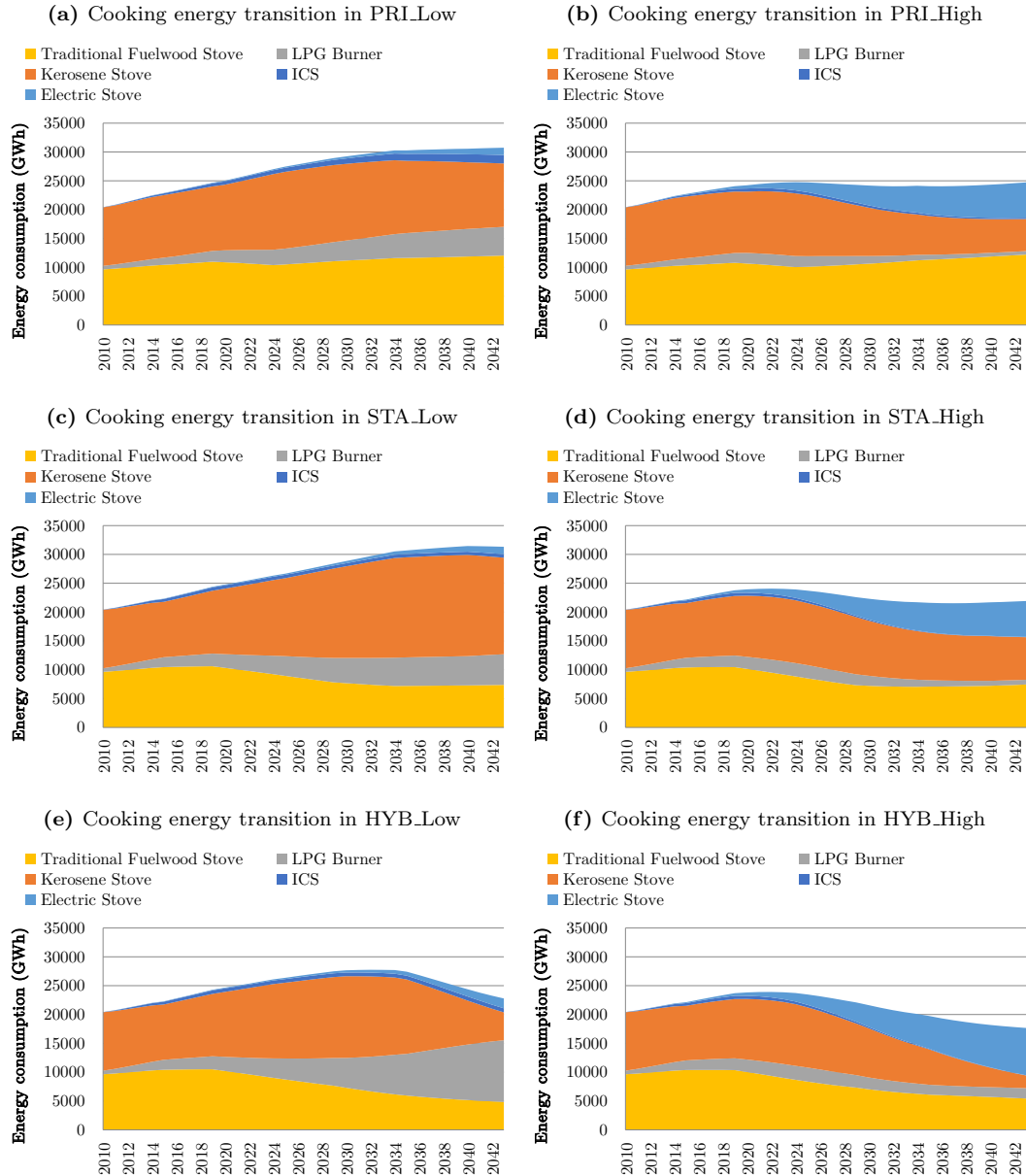
**Figure 8.18:** Cooking energy transition in Lagos–LEAP scenarios



Energy for cooking in PRI (Figure 8.18b) — which tracks REF (Figure 8.18a) closely in share of energy mix over the model timeline — does not peak within the model horizon, but displays slower growth from about 2020; likely as more efficient cookstove use grows, and later on, the slow down in population growth. This continued growth in cooking consumption in PRI is due to increasing use of energy-intensive traditional biomass stoves as compared to STA (Figure 8.18c) and HYB (Figure 8.18d), where traditional stove use decrease respectively relative to the base year. In all scenarios but HYB, the use of the LPG stove increases but begins to decrease slowly from 2020 as electric cookstove use increases. The continued slow rise in the use of LPG in HYB, together with increasing use of the electric cookstove, is joined with sustained reduction in both kerosene and traditional fuelwood

cookstove use. Whereas in PRI, the electric cookstove displaces kerosene stove use, but not fuelwood use. In fact, the sharp decline in kerosene use from 2024 coincides with a sharper increase in the use of traditional fuelwood in PRI; indicating some kerosene transition to fuelwood. Before drawing conclusions from the above insights, it is useful to examine the transitions that occur under the lower and higher variants of hourly reticulated electricity provision, as depicted in Figure 8.19.

**Figure 8.19:** Cooking energy transition across scenarios for low and high variants of level 3



Again, the outputs of the High\_RetE scenario variants are similar to the outputs provided under the original assumptions for level 3, but the Low\_RetE scenarios provide greater

variation. The use of electric cookstoves is — as expected — limited across all Low\_RetE scenarios, since non-electric cooking is more reliable when networked electricity is erratic and households try to ration the operation of their private generators; a situation further exacerbated by the fact that gasoline generators relied upon by poorer households are incompatible with the capacity required to operate electric cookstoves. Interestingly, fuelwood consumption decreases at a faster rate in Low\_RetE scenarios than in High\_RetE scenarios.

The first notable lesson from the scenario outcomes in Figures 8.18 and 8.19 is the possibility of traditional/transitional fuel–technology combinations displacing each other for a given energy service. In the base year of Lagos–LEAP, kerosene and fuelwood are the dominant household cooking fuels in intensity of use. As the original scenarios observed, electric cooking benefiting from the level-3 assumptions regarding hourly reticulated availability. In PRI (Figure 8.18b), as kerosene loses a large share of its cooking use to electricity, there is a notable acceleration in its reduced consumption from 2024 that coincides with increasing fuelwood consumption. Furthermore, comparing across the High\_RetE and Low\_RetE scenarios, there is *higher* reliance on fuelwood in the scenarios of the former relative to the latter, and *lower* reliance on kerosene in the former relative to the latter. It serves to provide further indication of kerosene displacing fuelwood use and vice versa, albeit under the influence of electricity availability — which displaces kerosene.

Drawing from this, it can be seen that absent effective availability and affordability of modern energy services, it is possible that with attempts to withdraw support for household fossil fuels — such as the removal of fossil fuel subsidies with the aim of making modern energy services more competitive, as is widely advocated — there is a possibility of an unintended transition to fuelwood for cooking. This dynamic was observed with participant H44-IT in Chapter 7 amidst kerosene price instability (see Section 7.3.3).

On the other hand, HYB (Figure 8.18d) and HYB\_High (Figure 8.19f) show that it is possible for electric cooking to capture a large share of the market for both kerosene and fuelwood; where the majority of kerosene users transition to the use of electricity cooking, and a fair share transition away from fuelwood relative to the base year. Similarly, under the assumption that there is limited increase in the hourly availability of networked electricity to households, HYB\_Low (Figure 8.19e) shows LPG can also capture a significant share of kerosene cooking consumption and that of fuelwood cooking. It suggests therefore, that an efficient approach to facilitating modern cooking energy transitions is the targeted market development of a relevant modern fuel for a particular case (local, state or national); which when made accessible (available and affordable) to a wide range of users, can effectively displace traditional and transitional energy services. The effort required to ensure availability and affordability — in what is a complex and dynamic social–energy interaction, as Chapter 7 reveals, requiring multiple technology types, multiple means of locating the di-



mensions of the energy service, multiple types of transactions, and others — can perhaps be most cost-effectively achieved when fewer, and most relevant, modern fuel types are being promoted for each case. This agrees with recommendations of neutrality as an enabling factor for energy access, with strategic harnessing and development of local resources for energy access (Rehman et al. 2012, Bhattacharyya 2012).

But there is an important balancing act required. HYB.High shows that any policy/strategic efforts to develop LPG cooking transitions could be wasted in the presence of favourable transitions to electric cooking. However, if LPG cooking transitions are not promoted, and the transition to electric cookstoves for many households is difficult despite higher average hourly availability of electricity, the result can be a relatively unchanged level of overall kerosene consumption for cooking by 2043 relative to the base year, as seen in STA (Figure 8.18c) and STA.High (Figure 8.19d); or worse, that kerosene consumption increases by more than 50 % in 2043 relative to 2010 as observed in STA.Low (Figure 8.19c), under limited electricity availability.

Finally, contrasting the kerosene and fuelwood transitions observed in HYB.Low with those of PRI.High (Figure 8.19b) and STA.High, presents an argument on the importance of alleviating energy stacking by prioritising the form of modern energy service (i.e. tier level) delivered over the number of households being reached by any form of energy access. According to the scenario assumption variants for level 3, the former scenario (HYB.Low) has only 20.5 % of households that receive the *respective* ‘high’ subcategory level of hourly reticulated electricity availability across the different settlements by 2043, while the latter two scenarios have almost 98.7 % of households in each settlement receiving this increase in respective hourly supply (see Table 8.16). Importantly however, Table 8.3 shows that for certain settlement regions — or households that have energy engagements commensurate with those of certain settlement categories — the higher subcategory of hourly electricity availability still ranges around tier 3 or less (see Table 2.2), and for some income categories, the private generation response capability is very limited. Therefore, even though many households in the latter two scenarios are able to adopt the electric cookstove under higher networked electricity availability, the continued irregularity of supply necessitates widespread stacking with traditional/transitional cooking services, and thus, the sustained dominance of kerosene and fuelwood consumption. Whereas in HYB.Low, though electric cookstoves cannot be facilitated due to the continued limitation of reticulated electricity availability, a high number of households were able to achieve *dynamic* access to LPG cookstoves (e.g. tier 4+ for cooking — that is, access to modern cooking in a sustainably affordable and available manner (see Table 2.1)) such that kerosene and fuelwood see a significant fall in their cooking consumption share by 2043.

It can be challenged that under the difficult task of providing energy access, prioritising

the tiers of access over the number of households receiving any tier of modern energy can lead to the situation found in STA\_Low, where limited success in providing dynamic LPG access leads to a growing reliance on kerosene cooking. Nevertheless, the figures show that household energy transitions take time, and the transitions to modern energy services need not be a smooth progression. In HYB\_Low kerosene consumption grew considerably before peaking around 2030, after which it fell at a rapid rate as LPG use took over. Therefore, it is conceivable that the situation in 2043 of STA\_Low can also represent a peak in kerosene use similar to that in 2030 of HYB\_Low, after which the fruits of any actions to ensure dynamic (high-tier) access to LPG materialise; simply illustrating a process where a longer time period is required for the transition to take effect. But when the transition does take place, there will be a limited period of energy stacking that leads to sustainable displacement of traditional and transitional energy services, for a sustainable eradication of energy poverty. In PRI\_High and STA\_High, electric cooking increases quickly from 2018 and steadies off from around 2036 to ensure kerosene and fuelwood maintain strong presence in the cooking mix by 2043; likely to continue unless dynamic access to the electric cooking service is fostered. This sustained energy stacking, which is most prevalent when lower tiers of modern energy services are accounted for as energy access provision, can lead to policy wastage and a burden on the poor; as multiple types of energy services are still being relied upon, and not all can be effectively supported by policy.

The HYB and HYB\_High scenarios present a most desired situation where kerosene and fuelwood cooking are largely displaced (as depicted in Figures 8.18d and 8.19f respectively), and there is very limited reliance on private fossil fuel-based generation of electricity (see Figures 8.16 and 8.17b). But, as the cooking transitions of PRI\_High and STA\_High show in Figure 8.19, the success of HYB and HYB\_High was not because of marginal increases in the hourly provision of electricity to *all* households — which was the case in the former two scenarios — but rather because a higher number of households were able to achieve changes to their organisation of daily life and livelihood resources such that they had reliable availability and affordability of electricity provision that was suitable enough to meet most of their dynamic energy service needs.

## 8.7 Conclusion

This chapter explained the details that form the purpose-built Lagos-LEAP household energy demand model used to answer research question 3. The model's innovative approach relied on hierarchical accounting of energy demand, as a product of demographic activity (percentage share of households) and energy consumption intensity, to explore the household energy transitions between 2010 and 2043 in three pathways that prescribe different external (decision) environments in Lagos state and Nigeria. The modelling approach of Lagos-LEAP

seeks to support other developing country energy demand models and energy system models, as a tool for identifying the potential transitions in a case region, from which opportunities and pitfalls for energy policy/strategy can be elicited. Given the model's responsiveness to its database, there is a need for future strengthening of secondary data at the household-level in developing countries; particularly in making data collection methods more responsive to the particulars of energy poverty. Furthermore, a participatory approach to scenario development and database development in policy work adopting this modelling concept, will ensure an even more rigorous approach to generating valuable insights. There is also opportunity for future work to further develop, and examine more closely, other areas of Lagos-LEAP that this model did not examine; such as transitions concerning non-poor households e.g. refrigeration and air conditioning for energy efficiency considerations.

The outputs of the scenarios modelled provide a number of insights for facilitating sustainable household energy transitions in Lagos state, which also serve as relevant considerations for other contexts:

- There is a possibility of traditional energy services being displaced by other traditional energy services, due to the relatively easier access households have to their use compared to their modern counterparts. Therefore, any policy mechanisms that seek to discourage the use of traditional energy services should be taken with care, as unfavourable transitions may be the result and the poor may be subjected to deeper energy poverty.
- Following on from the first point, it is important that *dynamic* access — that is mindful of the different social-energy interactions that different household-types will have with modern energy — be the strategy for facilitation, before steps to make modern energy more competitive in the marketplace by penalising poor energy services.
- In a sector that faces real challenges channelling finance to the sector, it is important that a strategic approach to resource harnessing and development for modern energy service provision be adopted, to achieve lasting results and prevent wastage of limited resources.
- The most effective way to sustainably get households to displace traditional energy services with modern energy services is through the use of higher-tier energy services; which under the right availability and affordability of *needed* service supply, can meet the dynamic nature of their energy service needs.
- The energy access transition is a continuous matter, and getting a population out of energy poverty can take time. Therefore, important are the substance of transitions not the speed, and the sustained discontinuation of harmful energy services over and above

the commencement of *any* form of clean energy service — because energy stacking can still represent energy poverty.

## Chapter 9

# Conclusions

## 9.1 Overview

Human engagement with modern energy services is foundational to social and economic welfare. Yet, decades of increasing research and action to facilitate this engagement, for the global population deprived of it, has made slow progress and revealed the complexity of this problem. Focusing on the process of change required for the activities of households in the developing world, this thesis set out to theoretically and empirically explore how traditional energy services can be sustainably displaced by modern energy services. The investigation examined concepts and experiences in existing literature that could explain the nature of the above transition, used the experiences of households from a relevant energy-poor case in Nigeria to explain the key drivers behind the energy transitions of the energy poor, and explored what the evidence reveals about approaches to energy access policy.

The questions that shaped this research and the approach taken to answer them sought to tackle some gaps and neglected areas in the field of energy access; both in knowledge, and how the gain in knowledge is sought. These included: postulating a concept on the relationship between households and energy that lead to observed energy transition outcomes; a holistic treatment of household energy services, which is often treated with a focus on a particular household energy service, fuel, or technology; obtaining evidence from the field explaining the household-energy interaction on the basis of historical experiences with all forms of energy, as opposed to evaluations of recent modern energy provision/adoption; and the development of an approach to exploring future household energy demand possibilities for decision-support that gives greater attention to the energy system characteristics of developing countries.

The remainder of this chapter is set out as follows: Section 9.2 synthesises the principal findings of this research that resulted from answering the research questions outlined in Chapter 3. Section 9.3 gives a final judgement on the thesis' aim. Section 9.4 discusses the limitations and boundaries of this study, before Section 9.5 offers potential areas for future research.

## 9.2 Principal findings

Ongoing debates over what is needed to sustainably achieve universal energy access broadly surround the suitability of technical solutions and the mechanism for delivering these solutions that are typically catering to households at the base of the pyramid. Existing literature shows that contemporary efforts to provide energy access often lead to the combined use of modern and welfare-inhibiting traditional energy services; thereby calling into question the long-term effectiveness of these efforts to increase human welfare. This thesis therefore sought to explore the reasons for these realities and how they can inform ongoing debates by asking the following research questions:

1. What explanation can be given for the energy behaviour of the energy poor, and thus, the nature of their transition to modern energy services?
2. What do the lived realities of households in rural Lagos reveal about the energy decision-making of the energy poor, and the drivers of sustained behaviour change?
3. How might the energy demand of households in Lagos state evolve in the medium to long term, based on alternative pathways for the drivers observed, and what can this inform about facilitating the transition to modern energy services?

### **9.2.1 Explaining the energy service transitions of the energy poor**

There are a complex set of interactions that explain household energy behaviour over time as the energy poor ultimately seek to secure the services that sustain, and where possible enhance, their livelihoods. In the practical fulfilment of their most fundamental human desires (basic capabilities), household energy behaviour can be explained as being guided by trade-offs between the urgency of an activity to facilitate their human desires, the existence of options to fulfil that activity, and the livelihood resources available to the household and any constraints they present. Therefore, the first conclusion of this work is that it is possible, a priori, that when the livelihoods of households become incompatible with traditional energy services, sustainable complete transitions will be the result; otherwise, energy stacking and unsustainable transitions remain a possibility.

The energy ladder and energy stacking theories, that hitherto form the basis for analysing developing country household energy behaviour and transitions, are limited by their over-reliance on income as a descriptor of change. While household income is relevant and important to this change, studies have presented a plethora of interrelated personal and external factors that work to shape energy behaviour/behaviour change. Income is a useful descriptor of a household's monetary capability or willingness to commit to an energy service transaction, but falls short in its explanation of other human interactions with energy that influence behaviour and transitions — interactions that go beyond purchase transaction to include aspects such as transportation, setup, use, maintenance and disposal; all cutting across both the fuel and technology dimensions of an energy service. This means that observed willingness to buy, which might justify commercial participation, does not explain impact amidst changing individual and external circumstances.

It is important to acknowledge that households cannot logically or efficiently consider the full spectrum of factors that can determine their every interaction with energy. An example of this is the inability for some of the energy poor to consider harmful externalities associated with fuelwood cooking when they seek to maintain its use despite access to cleaner cooking services. So, households may desire a particular way of living and specific

improvements to their livelihood, as shaped by their personal values, norms, beliefs, habits, capabilities and external conditions. Their entire scope of livelihood resources will place constraints on the achievement of these desires. Therefore, the decisions that shape how they organise their lives over any given period of time will involve prioritisation. Prioritisation of the most fundamental capabilities to fulfil, daily activities, the modes by which activities are undertaken, and more; all of which impact the livelihood capital(s) a household may decide to trade-off.

If sustainability of livelihoods is at the centre of it all, then the absence of a modern energy transition is because the modes by which it is/must be interacted with infringe on livelihood sustenance. An unsustainable transition is because this infringement happens later in the future. As Chapter 7 revealed, this is the case even when the activity to be fulfilled is urgent to a household, so long as there are alternatives. An incomplete transition is because the traditional energy service is needed for livelihood sustenance, despite modern energy interaction. A sustainable complete transition occurs when the modes by which households interact with traditional energy services infringe on livelihood sustenance, in the presence of suitable modern energy access.

The above can be observed to be true from documentation of experiences in countries such as the U.S., China, India and Mexico; where changes in the labour characteristics of the energy poor made manual fuelwood collection incompatible with their new-found daily routines, leading to sustainable transitions away from the fuel (see Chapter 4). Their jobs represented an important provider of monetary capital and an important destination for human (time) resource/capital. This change in labour characteristics and access to alternative energy services requires changes in the social, economic and technological makeup at the local level that not only involve locals but other diverse participants, to raise the capacity to maintain, learn from and enhance socio-technical changes. The process of transitions cuts across multiple sectors, and involves multiple actors, working towards a clearly articulated goal.

## **9.2.2 Realities of household energy transitions in rural Lagos**

The vocational activities of persons within a household are central to how they organise their daily lives and the livelihood resources available to them for other engagements. Therefore, it serves as a major driver of energy service decision-making and resulting transitions. The experiences of households in rural Lagos showed that the existence and influence of varied personal histories, mean that it is difficult to legislate for household energy behaviour according to social and economic characteristics; however, contexts do have an important bearing in shaping basic desires and the urgency of the modes by which they are fulfilled. Nevertheless, this work found that because of the subjective nature of household behavioural



responses, the most effective way to achieve sustainable complete transitions to modern energy services is if the manner in which households organise their daily lives made traditional energy services inaccessible for acquisition or use.

Drawing predominantly from 83 semi-structured in-depth interviews with 67 participants from diverse communities in rural Lagos, about their lives, historic energy interactions, and the forces that have led to their lived transitions, this study provided evidence on not just what the energy behaviour and transitions of the energy poor are like, but *why*. This explanatory contribution of this research plugs a gap in the field which previously observed important relationships and transition drivers absent a deeper understanding of the forces at play.

For example, analysis of survey data collected for a particular case can find a link between formal employment and the use of modern cooking services (see Chapter 4). This work showed that this is because of the livelihood resources households can afford to trade off as they seek to meet this urgent demand of eating. The smallholder farming households of Epe found it suitable to maintain fuelwood cooking as part of their cooking energy stack, in a country where slack implementation of forestry resource management procedures makes fuelwood freely collectible by rural dwellers. But as occupations ensured that daily activities of persons were increasingly organised away from the vicinity of freely available fuelwood, the livelihood capital trade-off for acquiring the fuel takes on a different form — a form that involves greater human capital commitment than is possible, given its need for other important activities.

Chapter 4 highlighted Nepal, India and China as some of the countries presented in the literature to have found similar forces at play; where increased involvement with non-family organisations, increasing uptake of formal employment, and agricultural specialization, all work to transform rural livelihoods to use modern energy services and abandon traditional energy services. Thus, it is not just local involvement in energy access projects that is required, which recently rests on a narrow approach limited to local retailers of modern technology, but rather local transformation for productivity, for economic diversity, for social inclusion, for community access — all of which are necessary for sustainable energy solutions.

Furthermore, as highlighted in Chapter 4, studies have found that local knowledge and accessibility to a modern energy technology have correlated well with its uptake. This study showed that this is related to the reinforcing work that positive exposure to and experience with an energy service has on a person's/household's perception; notably, their perception of the importance an energy service or the secondary capability an energy service fulfils is to the sustainability of their lives. The contextually intriguing set of communities selected for fieldwork and the range of households interviewed, captured the influence that exposure to the lifestyles and services found in more developed regions can have on a set of people's

dispositions to energy services. The older generation of energy poor rural dwellers may see little reason for change in their organisation of daily living and habits for engaging with the energy carriers and technologies used, for example, in cooking to make their foods taste a particular way. However, the younger generation are more likely to be open to new opportunities; opportunity for new vocations, new organisational associations, new information, new ways of thinking, new predispositions and perceptions that rest on new energy carriers and energy technologies to prepare foods to the tastes they have grown and are growing accustomed to (see Chapter 7).

Therefore, the transferability of people, knowledge, technology and services between the urban and rural areas of Lagos, and Nigeria at large, is an important driver of the livelihood transformations that lead to a societal lock-in of modern energy service use. Infrastructure then, particularly transportation infrastructure, is a necessary precondition for this transfer of resources, and by extension for sustainable energy transitions; but this is rarely factored into strategies for achieving the global goal.

The experiences of households in rural Lagos supported the concept developed in Chapter 4, explaining the sustainability of household energy transitions. They further revealed that traditional energy services may take longer to phase out or may be at risk of continued use if left accessible to users; where use or non-use is based on their personal attitudes toward the energy service. Despite the poverty characteristics of the kerosene lantern, many households maintained its use. Despite the energy-poor characteristics of the kerosene cookstove, it was still considered a service to aspire to and was highly relied upon amidst relatively difficult access to the LPG cookstove. So, making modern energy accessible is important, but energy stacking can be the result. But for the discontinuation of energy-poor services on a broad scale to be more likely, they have to become inaccessible to their current users.

Attempting to increase inaccessibility through restrictive/penalising policies can threaten the livelihoods of the poorest — who rely most on these fuels — through energy inequity and/or injustice (e.g. subsidy removal). This inaccessibility is best achieved through progressive transformations in the way people live their lives; such that engagement with harmful, inefficient, traditional energy services threatens the sustenance or opportune progress of their lives. A simple example from the case involves those who are unable to make use of fuelwood cooking due to the absence of outdoor cooking facilities in their rented accommodation. Or those who have forsaken the consumptive use of fuelwood for household cooking due to the locational requirements of their jobs. These are the sorts of transformations that drive sustainable displacement of traditional energy services with more modern energy services, and they can be most effective when they are based on improvements in the welfare of the poor.

### 9.2.3 Possibilities of household energy transitions in Lagos

This work's exploration about the future of household energy demand in Lagos revealed the importance of treating energy access as a continuous issue; the mechanisms that bring access must also be suitable to sustain access to achieve long-standing eradication of energy poverty. Considering this, an effective and resource-efficient way to facilitate the transition to modern energy services is through the provision of energy services that have the capability to meet the full scope of household needs. Any policies implemented against energy-poor services in the hope of promoting cleaner energy service adoption must ensure dynamic access to the latter or risk deepening the incidence of energy poverty.

The use of the Lagos-LEAP model developed for this research, the first bottom-up model of Lagos' household sector, enabled the incorporation of developing country energy system characteristics that are typically omitted due to the difficulty of their incorporation. But their inclusion is an important starting point for being able to model energy poverty issues in a way that informs policy opportunities and pitfalls. This is crucial in a sector that has limited room for wasted resources with the aim of solving an urgent sustainable development goal. Because if, as revealed during fieldwork interviews, participant H13-IG is prepared to turn off all electric light bulbs in his home, in order to facilitate the power feed from his generator for his television services and rely on the television screen's light for vision, then a little added nuance is useful for examinations to support energy policy decision-making. As noted in Chapter 3, this behaviour is not limited to the context of Lagos, and there is evidence in other regions of the globe of households maintaining kerosene lighting in order to prioritise SHS for television viewing. Therefore, the modelling concept used to capture the broad features of the above reality, such as energy stacking and the influence of differences in the primary source of electricity, sets a precedent for other models of developing country energy systems aiming to capture some of the more salient issues in those contexts.

An important lesson from the process of developing the Lagos-LEAP model is the need for concerted action towards the improvement of data to support work on energy access. If developing country data collection procedures can be more robust and innovative, in not just capturing relevant social and economic divisions but acknowledging the practice and importance of energy stacking and energy insecurity on energy behaviour, more informed decision-making can be made on the subject. In this study, which made use of various data resources to incorporate these behavioural considerations, scenarios of future energy consumption showed that just as it is possible for electricity to displace the use of kerosene for cooking, if the nature of supply is weak in its ability to secure the dynamic cooking demands of households, the result can be a continued increase in traditional cooking. This has important implications for energy policy; and can inform, *inter alia*, the useful order/timing

of policy action according to fuel and technology support, funding requirements and any policy on redistribution of funding.

The complexity of policy decision-making, given that certain fuels cut across multiple activities and sectors, and the cross-service influence of household energy behaviour, makes a holistic treatment of household energy access necessary; both in research and in action. Dedicated projects, lobbying, awareness campaigns, training, and policy action that is limited to energy for lighting services alone, for example, risks unintended consequences for other household energy service demands. Remembering that in the developing world, cooking accounts for circa 90 % of household energy consumption, with a poverty profile that is multidimensional in its impact as it pertains to indoor air pollution, women and child drudgery, unproductivity and more, then there is a need to consider how modern lighting technology policy might impact household cooking energy transitions, and whether or not projects for lighting and non-cooking electrical appliance projects are enough to constitute energy access or the eradication of energy poverty.

### 9.3 Thesis conclusion

The thesis concludes that to achieve sustainable transitions to modern energy services, where the energy poor *substitute* traditional energy services by modern energy services, then as opposed to using modern energy to change people's lives, the international community needs to change people's lives to use modern energy services.

But firstly, as Chapter 2 discussed, it remains unclear what the global goal is. Nor is there clarity on whether the use of modern energy services alone constitutes energy access, or modern energy use *in addition* to the displacement of traditional energy services constitutes energy access. There is a difference between the two household energy profiles. The former can provide access to welfare-improving and monetary value-adding services, while the latter adds the discontinuation of energy services that erode productivity, damage health and more. Given the observed nature of traditional energy use amidst insufficient or insecure modern energy access, it can be argued that energy stacking still constitutes a form of energy poverty. Nevertheless, this is an issue which lacks consensus on definitions surrounding energy poverty/access that the global community needs to address to aid concerted action towards the global goal.

This is particularly important because different communities of interest have different views on what energy poverty is, and what energy access will look like, amid different developmental priorities. While there is a global need to tackle climate change by making major strides in the channelling of renewable energy into the energy mix and greater efficiency in major consuming sectors, poorer countries have a need to fast-track their national development at least cost, just as developed nations seek to make their energy systems resilient

to global markets. These multiple and diverse agendas in a globalized world can place a strain on united agendas; and it has been shown — as observed in successful national transitions discussed in Chapter 4 — that unity in polycentric action is an important means for achieving goals that are based on many moving parts.

The Sustainable Development Goals (SDGs) aim to foster such unity; and since 2012 through to the inclusion of an energy poverty dimension in SDG7, global recognition has sought this united action towards the goal of universal energy access. But moving from the micro level to the macro level, united action becomes ever more complex and difficult to achieve. The Federal Republic of Nigeria, amidst its many social, cultural and political divisions, can find unity in relatedness, based on multidimensional poverty and energy poverty that is felt across all state and geopolitical regions of the country. This is an important foundation the country must utilise in its development ambitions. But while energy poverty exists across the developed and the developing world, Chapter 2 discussed their very different forms, which has resulted in two separate fields of research and communities of action. A definition of energy poverty that captures the issue as it relates to the developed and the developing world — and flexible enough to respond to contextual diversity — may be an important development in the bid to finally achieve consensus on the definitions by which energy poverty is said to be addressed by energy access (see Bouzarovski & Petrova 2015, Day et al. 2016).

This is pertinent because actors from the developed world are at the forefront of solving *energy poverty*, as it relates to developing countries. Given the differences in national priorities, the different stages of development across the Global North and South, and the undeniable trade-offs that exist between some of the needs of energy access, climate change, and other development priorities (see Fuso Nerini et al. 2018), if a fundamental state of energy for well-being and development that speaks to the expectations and standards across all regions of the world cannot be achieved then different stakeholders can question the level of justice and equity being opted for in solutions proffered.

Currently, pico-solar technologies play a dominant role in the stand-alone household energy technology sector in terms of the number of households served, as discussed in Chapter 3. They have been judged beneficial to the energy poor on the basis of better quality illumination, safer use, and long-term savings against foregone traditional fuel purchases such as kerosene; and in some cases, the added benefit of a mobile phone charging service. The practice of energy stacking raises questions over the first three benefits, but even when this is not the case, pico-technologies have a very limited scope for addressing some of the major poverty outcomes of a lack of access to modern energy services. This work did not examine energy to community institutions, but just as discussed in Chapter 3, a lack of electricity to health centres is just as much an energy poverty priority as a lack of mod-

ern energy services for household consumptive purposes; perhaps of even greater priority. And this extends to other community energy demand requirements; such as street lighting, schools, and water provision.

Importantly, as this work has shown, enhancing the above services and other value-adding activities shapes household livelihoods to align closer to modern energy than they do traditional energy services. A more comprehensive definition of what it is to be energy poor and have energy access — one perhaps that speaks not only to the possibilities and impossibilities of the present, but of future aspirations, and captures fundamental human aims and desires that are observed across the developing and developed world — would give practitioners a better gauge for what the energy access priorities and strategies should be.

Research on the linkage between energy and development points to the presence of bidirectional forces (Adams et al. 2016). On the relationship between energy poverty and development, Bordoff (2014, p. 353) correctly states: “Economic growth is ultimately what provides countries with the resources to expand energy access, creating a virtuous cycle as more energy access boosts growth and pulls people out of extreme poverty”. But energy is needed for economic growth to begin with, which is why O’Brien et al. (2007, p. 614) present the paradox that, “the energy problem cannot be solved without solving the poverty problem and the poverty problem cannot be solved without solving the energy problem”. Based on the above statements, the experience of other countries discussed in Chapters 3 and 4, and the evidence emerging from fieldwork discussed in Chapter 7, the paradox of O’Brien et al.’s statement can be solved by articulating differences in what energy is being provided for. Prioritising the provision of energy, *initially* for activities associated with the external environment of a household that shape societal and economic productivity — such as industry, infrastructure, critical public services (healthcare, education) — is foundational to the (multidimensional) resource and capabilities transformations needed to achieve energy transitions in household (consumptive) activities. The initial provision of energy is for activities that change people’s lives, and these changed lives facilitate the use of modern energy services as opposed to traditional energy services; enabling a virtuous cycle that sustainably improves the welfare of peoples and nations.

In recognition of this, the manner in which limited financing is utilised becomes critically important. Indeed, there may be opportunities for channelling more financing to energy-poor regions, if it can be acknowledged that sustainable energy transitions can benefit from developing capabilities that will make for a more investment-friendly cost-benefit profile; such as those related to national connectivity and productivity of national resources. For Nigeria, this can mean acknowledging — as being important to enable lasting energy access transitions — the need to develop rail and road transportation, supported by a stable market for domestic gas supply for power generation, and also to power industry and

public services, by which development of capacity in strategic areas of the value chain for relevant renewable technology can be fostered, and more; all of which, under the right political circumstances, can be more appealing to private finance. But unstable environments (politically and financially) are at the heart of the ills that bring about energy poverty and poverty in general, and they must be considered as important issues to be addressed.

Such a multidimensional approach to energy access, that incorporates focus on capital-intensive activities with long lead times, will likely take the course of action beyond the 2030 timeline. It can be argued therefore, that the severity of energy poverty is such that it is better to prioritise incremental steps that reach more of the energy-poor with *some form* of modern energy access faster, at the expense of providing energy services that can be dynamic to the needs of households. Indeed, it is important for continued activity towards quick and direct results to alleviate energy poverty — particularly in cases where people have experienced intrusion on their freedoms and rights; such as in the refugee camps of internally displaced persons (see Franceschi et al. 2014) — but it must be done with long-term thinking and service provision that leave room for growth without burdening the poor. Nevertheless, it is worth examining the *true* impact of incremental steps to alleviate energy poverty in relatively stable jurisdictions, in knowledge of the realities of energy stacking, unsustainability and community-service energy poverty, in order to better judge the need to err on the side of speed or rigour in the fight to achieve the global goal.

## 9.4 Limitations of study

While the strategy adopted in this thesis presented much relevance for exploring the nature of household energy service transitions in developing countries, there are some inevitable limitations to the approach taken. Some of these have been discussed in previous chapters.

The fieldwork undertaken to answer the second research question relied on a single region — Lagos state in the West African country of Nigeria. A wider breadth of evidence could have been achieved if other contexts from the developing world were added to the fieldwork process. Chapter 5 acknowledged the resource limitations that encouraged this single-region approach and elaborated on the strategy of community selection that would aid transferability and a broad range of community-types for robust insights. Nevertheless, there will be cultural and situational forces that are specific to the case region. Differences in these forces for another case may bring forth alternative results if the study was repeated. For example, the transition or non-transition forces observed in the work born of the practice of outdoor fuelwood cooking in Lagos may differ for other regions where indoor fuelwood cooking is common practice.

The study also rested heavily on the insights of the local households. While this was a boundary set purposely around the work undertaken, post-examination recommendations

can receive added value if analysis includes a more rigorous insight into the perceptions and capabilities of other important stakeholders in the energy access scene of the country. Interactions with these stakeholders were limited to the purpose of building the context to strengthen household and community interactions.

The Lagos-LEAP model rested on a database that required some assumptions to be made about current and future energy behaviour across certain consumer groups. While these assumptions were based on information obtained from multiple and varied sources, a stronger foundation for the modelling approach adopted — which was sensitive to the database attributions — would be the use of dedicated data collected and structured according to the requirements of the model methodology. Furthermore, as stated in Chapter 8, the use of this scenario approach in decision support that can draw on a more participatory approach to the construction of the model database and the scenarios projected will be most suited to the modelling concept. While the modelling concept does not analyse results according to the forces that drive scenarios, the different scenarios that provide pathways to compare can be strengthened by an approach that goes further than stakeholder consultations.

Finally, being the first of its kind, the Lagos-LEAP bottom-up model is limited by a lack of aggregate energy records for the case region by which the model could be validated; meaning that model outputs could only lead to broad recommendations. Due to the modelling methodology, some of the more specific policy examinations of other energy system models — particularly possible in top-down models — were not feasible in Lagos-LEAP; such as evaluating the impact of price on behaviour and the potential cost of observed scenarios, which would provide further value during policy decision-making.

## 9.5 Future research

The findings of this research open up other areas of future work, some of which are ongoing areas of exploration in the field today. To begin with, there is an opportunity for future work to respond to the limitations of this research and the aspects it could not explore as outlined in Section 9.4.

Further testing of the concept presented in Chapter 4 through fieldwork in other contexts, both in Nigeria and areas of other developing countries, will be of use in strengthening the understanding of reasons for different types of observed energy behaviours and transition over a period of time. Useful insight can be obtained from other methods of social research. This includes the use of ethnographic methods that incorporate participant observation over an extended period, and is geared towards understanding the relationship between household livelihoods and energy — according to its different dimensions of energy and the different modes of interaction from acquisition to disposal. This would give a different view on any



drivers, synergies, or trade-offs leading to specific energy behaviours that users themselves may not consider or recollect in an interview-only process.

In some regions of South Asia and Latin America, there have been decades of local experience with modern energy services. Social research in some of those contexts can provide insight into some of the transitions observed in the presence of more modern energy services, and some of the drivers of sustainable complete transitions. This would be particularly beneficial to examine whether some of the conditions for different transitions observed in this research are observed true for the transitions experienced with modern energy services implemented under specific programmes in decades gone by.

Another area not focused on in this study that is worthy of further work is on the supply-side of household energy transitions, and supplier experience with changing consumer demand as the external decision environment shifts in particular contexts. This, as mentioned in the previous section, would add further value to the understanding of some of the non-energy transformations that are required to facilitate sustainable and complete household energy transitions. The demands and requirements of energy suppliers vary according to the type and the realities of the environment in which they operate. So, a detailed examination of the intricacies of their experiences in view of the changing socio-cultural, natural, technological and political landscape can present useful insights.

Further expansion and application of Lagos-LEAP's modelling concept — potentially modelling beyond the residential sector — could be adopted in a participatory process, as part of work to strengthen the state's development planning. It will also be usefully applied at the national level, in light of Nigeria's ongoing power sector reform process that retains many uncertainties — for example, in the areas of future energy mix and subsidy redistribution.

Post the fieldwork period of this research the government withdrew subsidies for kerosene and gasoline in response to budget pressures resulting from: dwindling reserves of hard currency following a fall in global oil prices, and maladministration of the subsidy process that facilitated a black market for these products to the detriment of the poorest and most vulnerable (IISD 2016). Although the energy poor, particularly the rural energy poor already purchased kerosene at black market prices, limited action to further strengthen the distribution channels of household fuels in the country can mean knock-on effects of the above policy decision; effects that further diminish the availability and affordability of the fuel for rural dwellers. A useful avenue of future work is to examine the effects of these policy decisions on energy behaviour at the household level and on state/national consumption to compare with the inferences made in this research. Depending on the change in accessibility indicators (price and community supply) of kerosene, the accessibility of more modern cooking and lighting energy services, and the accessibility of more traditional cooking and

lighting energy services, some households may find the fuel too urgent to discontinue, some may find it inaccessible and rely more heavily on fuelwood for cooking, others may respond with greater reliance on LPG either exclusively or in an energy stack. Examining the forces that drive these changes will present interesting areas for deepening knowledge.

Insights from this research present further reason for a clear definition of energy poverty/energy access that speaks to the issue as it relates to realities of both the Global North and South. New and increasingly competitive technology presents an opportunity for the developing world to leapfrog the inefficiency/climate-polluting ills of energy systems in the developed world. However, the agenda for leapfrogging must not lead to stop-gap energy solutions that risk the long-term justice and equity of the energy poor; ultimately leading to wasted efforts. Conceptual and empirical work to present an all-encompassing aim of energy access activities, whether achievable through immediate (short-term) or transformative (medium to long term) action, is a necessary compass for meaningful and sustainable energy access for all.

There is ongoing work to examine the trade-offs and synergies that exist between the 17 SDGs (e.g. Fuso Nerini et al. 2018); another area, can involve deeper examination of the potential trade-offs and synergies between factors describing the external environment of a particular context and energy access activities.

An important arm of research in this field is on what types of energy access activities should be receiving what types of financing. There has been work on this looking at financing specifically for energy-related activities; such as financing to market participants at different stages of growth — during technology development, for working capital, and scale-up of activities — and for different types of participants, financing of larger-scale energy infrastructure in poor countries, as well as examinations of the use of financing modes that are relatively new to the sector, such as crowdfunding and structured debt financing (e.g. Bhattacharyya 2013, Orlandi, McCrone, Battley, Tyabji, Falzon & Lerner 2016). But if the inter-sectoral activities that enable sustainable energy transitions are acknowledged, there is room for some ambitious transdisciplinary work examining how limited financing for development should be directed. For example, in regions characterising the segment of the energy poor that is considered unable to afford modern energy services at market rates in the near future, it can be useful to examine whether it will be most efficient to direct private capital to activities of connectivity and productivity in such regions (e.g. improvements in infrastructure and agricultural productivity, inter alia), while concessional, donor and philanthropic finance are used to meet the modern energy needs of those last mile regions.

The increase in private activity to provide the energy poor with energy access has facilitated important strides in achieving the global goal. But going forward, efforts in practice and research must ensure that modern energy adoption is leading to traditional

energy abandonment.



## Appendix A

# Delving into the unknown

Part of the scoping study involved the identification of appropriate locations for fieldwork and to test an initial aim to use the Analytical Hierarchy Process (AHP) as a tool for users to make pair-wise comparisons on the importance of pre-identified factors influencing their energy service decision-making. During testing, there were clear difficulties experienced in uniformly communicating the rating scale of the tool to local participants in all interviews. Participants also found it difficult to adequately attribute ratings to what is a highly time-sensitive and shifting phenomenon. This threatened the study with a validity issue; which stems from inconsistent procedural aspects, such as the instructions given to participants, the questions being asked, and their understanding of the process (Seltman 2012). Overcoming this validity issue would be too difficult to practically implement in the multitude of interviews the study would undertake, and a shift in focus to the strengthening of the semi-structured interview process was the resulting decision — which ultimately was important for the success of the research as insights became more exploratory and richer.

Another important moment of enlightenment obtained during the scoping study was the need to utilise a translator to facilitate the line of communication between the researcher and many of the participants to be interviewed. During the scoping visit to the community setting, it was possible to test and understand the practical difficulty of conducting interviews with residents — the majority of which, did not have English as their mother-tongue. There existed a number of Yoruba (one of numerous indigenous languages) dialects spoken within the community, and the researcher's Yoruba was not particularly fluent. It was therefore important to utilise a staff member from CERUD to translate questions asked in English into Yoruba for the interviewees and vice versa for the researcher.

The use of a translator during the research process raises concerns about whose voice is being represented in the interview (Leck 2014). To facilitate an effective line of communication in this way, the translator was appropriately debriefed on the purpose of this research, as well as the nature of insights expected. A point was made to translate comments with

exactness, although as is the case with many languages, literal translations can sometimes be difficult. It was therefore helpful that the researcher has a basic command of the Yoruba language and could contribute to, and interpret discussions being had in a manner that enriched the conversations with participants.

A great strength to this research was the ability to maintain the use of the same translator over the two stages of the fieldwork process, as the translator's knowledge of the case being explored was able to grow in tandem with the researcher's; with constant discussions on the insights being obtained, it was possible to maintain a strong level of synchronisation in developing rich communication with the interview participants. A key part of ensuring a successful interview process and overcoming potential problems that could arise from the use of a translator was the decision to utilise the semi-structured interview approach, as it provided the avenue to utilise the strategies described above. There is further discussion on interview translation in Section 5.3.3.

## Appendix B

# Household Interviews: Question Framework

All questions presented in Tables B.1 and B.2 fall under one of the following categories, in terms of what they aim to elicit from the interviewee:

**Classification (C)** Questions asked to all participants interviewed during fieldwork in order to classify them.

**Status (S)** Facts about a participant and his/her household's current status or previous realities.

**Relationship (R)** Explanations about procedures, processes and activities respective to the interviewee.

**Perception (P)** Interviewee's current or historical opinions, and future expectations.

**Aspiration (A)** Hopes for the immediate and long term future.

Probing questions, which flowed out of interview conversations, generally assumed one of the above categories. The purpose of questions from these categories, is so as to allow participants provide direct *why* answers about their relationship with energy, but also for these answers to be validated by other answers given during the interview — indirect *why* answers. For example; **Perception** questions will provide the greatest avenue for receiving *why* answers about revealed energy service behaviour. However **Aspiration**, **Status**, and in particular **Relationship** questions will contain truths about observed/stated energy service behaviours that are either not revealed in perceptive statements, or serve to support statements made in response to **Perception** questions. This approach to questioning, that allows a holistic treatment of all issues, maximises the potential to identify interesting points of inquiry worth probing, and enrich the insights being obtained.

## Framework for household semi-structured interviews: Stage 1

The interview structure used in phase one is provided in Table B.1. These questions followed an official introduction and an explanation of the purpose of the interview, and interviewee provision of verbal consent to undertake and record the interview. All **Classification** questions were asked to every participant, according to relevance. As a result this initial section of the interview was more structured in nature, but it maintained flexibility for conversations to proceed naturally; and questions not included in the framework were often asked, in order to enrich the contextual background of each interviewee. The latter section of the interview, which has greater focus on details about services (energy and others) and livelihoods, was much less structured, in practice.

**Table B.1:** Question framework for household interviews during Stage 1 of fieldwork

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
<i>General participant info</i>		
• In which community do you live?	C	For clarification purposes in addition to classification; in case interview took place at workplace, outside home community.
• How old are you?	C	The age of a participant can inform the presence of any generational effects and creates a platform for investigating historical influences during the interview. Options were offered in brackets of 9 to minimise intrusiveness (e.g. 20–29; 30–39; etc.). Most households were happy with providing their exact age.
• What is your marital status?	C	The roles and decision-making of married men and women can be very different to those of their single counterparts. This question makes it possible to explore this.



table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
• How many people live in your home?	C	This provides an appreciation of the human resources, and potential energy needs of the household, which will aid questions asked in the interview.
<i>Residential status</i>		
• Are you an indigene of this community?	C	Gives an indication of the participant's history and origin.
• Are you a permanent or temporary resident of this community?	C	Provides an indication of the participant's (or participant's household's) daily, weekly, monthly, or annual residential situation, which can be used to explore energy behaviour and transitions over the course of the interview.
<i>Assets and finances</i>		
• Do you own your home or rent?	C	The sense of equity a participant has to their house may have an influence on the nature of energy services invested in, and the nature of the investment (monetary or otherwise).

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
<ul style="list-style-type: none"> <li>• Is your average monthly expenditure above or below ₦10,000?</li> </ul>	C	Income is one of the foremost drivers of energy behaviour. But there is an inherent difficulty in eliciting income information from a group of people whose incomes largely vary by season, still engage in small levels of barter transactions, and can have multiple sources of fluctuating incomes. It was therefore important to derive as much information possible on each participant's economic prosperity to support understanding during interactions; including their levels of expenditure, products of trade, land ownership, and primary observations about their environment. For classification purposes, expenditure was expected to provide a relatively clearer and more consistent depiction of household finances for participants to consider and recollect. Phrased to keep intrusiveness to a minimum, before participants were given the opportunity to provide further information with the next question. ₦10,000 (circa 2013 US\$2.5 per day) provides a threshold, below which, participant disclosure of finances can receive greater emotional significance and influence (Nigeria's official minimum wage in 2013/14 was ₦18,000). As Table B.2 will show, 'income level' elicitation was added in the second phase of fieldwork.
<ul style="list-style-type: none"> <li>• If above ₦10,000, what bracket of expenditure is it?</li> </ul>	C	Options given in brackets of ₦9,000 (e.g. ₦10,000–₦19,000; ₦20,000–₦29,000). Most interviewees provided specific values.
<ul style="list-style-type: none"> <li>• Do you own land?</li> </ul>	C	Classifies the participant by providing an indication of ties to the community.

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
• Do you use your land for farming?	C	Some households use their land for farming, some households rent their land to others to farm, and some households build houses on their land. It provides an indicator of the occupational practices of the participant's household.
• Do you use your land for subsistence or commercial farming?	C	An added classifier that indicates household prosperity level; which is useful to help shape questions asked during interviews. For example, in the case of commercial farming — how energy services influence their processing and sale of farm produce.
• Do you hire workers on your farm?	C	Another indicator of household financial capabilities.
<i>Other occupation(s) (entire household)</i>		
• Do you undertake any other income-generating activities?	C	Provides further information on how participants organise their daily lives; aiding the avenues of inquiry during the interview.
• What other occupations do those in your household undertake?	C	Provides further information on the activities of others in a participant's household, which will set the foundation for investigating how decision-making and responsibilities are shared.
<i>Cultural background</i>		
• If you are not an indigene of this community, when did you or your parents migrate?	C	Valuable insight into a participant's history, that provides avenue for exploring the influence of history and culture on energy behaviour and transitions.

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
• Did you migrate from a rural or urban location?	C	Helps to shed further light on the history and experiences of a participant and their family, that may have shaped their attitudes, relations, and perceptions discussed in the interview.
• What medicinal practices do you use? Does your family make use of the nearest health centre?	C	Literature on the communities and preliminary discussions suggested that a household's engagement with traditional or modern practices may be an indicator of their appetite for change. Medicinal practice is a typical example of this, where there may exist an aversion to either traditional herbal medicine issued by herbalists, or modern medicine and care at modern health centres.
• What is the marital status of your home?	C	The marital practice of monogamy or polygamy is something that is culturally accepted in the communities visited; and may have an impact on the energy services and behaviour of households.
• Do you own a mobile phone?	C	An important indicator, not only on the energy demand of the participant, but on communications and accessibility.
<i>Broad areas of household energy service inquiry</i>		
• What energy services do you use?	S	Necessary starting point of each investigation into the energy behaviour of participants and their households.

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
• Please explain how you interact with all your energy services	R	Explanations include: How they use each service, where they obtain each fuel and technology, how much they pay and how often, how long it lasts, etc. This area of inquiry and the one below, seek a holistic picture of a household's interaction with all dimensions of their energy service and how it fits into their lifestyle.
• Please explain how each energy service helps you with your daily activities	R	See the notes above.
• What do you like, and do you not like, about each of your current energy services?	P	Seeking the conscious perceptions consumers have about their energy services and their reasons for them.
• What sorts of improvements to your energy services do you hope for?	A	Seeking the current energy service knowledge and desires of a household, and their reasons for them.
• Are there any activities you would like to do but you currently cannot?	A	Exploring what the desires of a household can say about potential energy transitions, whether to traditional or modern energy services.
<i>Additional areas of inquiry in follow-up interviews</i>		
• How are decisions on fuel acquisition or use taken on a daily basis?	R	A crucial view into the decision-making mindset of a household in practice; as they are encouraged to think about decisions they have made that very day, and in the recent and distant past, and how they made them.

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
<ul style="list-style-type: none"> <li>• After seeing the features of these two solar lanterns, what impressions do you have of them?</li> </ul>	P	Two D-Light solar lantern types were taken to interviews to support exploration about consumer perceptions.
<ul style="list-style-type: none"> <li>• Which energy fuel and service is most important to your household?</li> </ul>	P	Encouraged participants to think about the importance of the fuel, which can be applied to different technologies for different services, vis-à-vis the importance of the service, which can be fulfilled by a range of options; and how these consciously or subconsciously influences their decision-making.
<ul style="list-style-type: none"> <li>• How do you feel about making purchases with an instalment payment plan</li> </ul>	P	Described a payment scheme being offered by a local LPG retailer to encourage low income access to modern cooking fuel. Helped to gain further insight on consumer impressions on some modern energy services, and validate some comments provided in previous interview.

## Framework for household semi-structured interviews: Stage 2

All the **Classification** questions used in Stage 1 of the fieldwork were applied in Stage 2. This was the same for most of the energy service areas of inquiry. However, the experience and insights coming out of the Stage 1 interview process and analysis, and the subsequent re-evaluation of concepts surrounding household energy behaviour and transitions, made it necessary to introduce further areas of inquiry during Stage 2 interviews. These are shown in Table B.2.

**Table B.2:** Additional questions for household interviews during Stage 2 of fieldwork

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
<i>Further broad areas of inquiry in Stage 2</i>		
• What is your average monthly income?	C	Used as a further descriptor of household finances. Provided an added avenue by which participants could consider, determine and recollect their monetary capabilities.
• What energy services used by your household in the past, do you no longer use? When did you stop using them? When did you begin to use the new energy services?	S	To explore experiences and patterns of energy and non-energy transitions. Details about the period, which can reveal potential reasons for change.
• Why did these changes happen?	P	Participant's perspective of the changes, which can be further compared with other indications of the reasons for change.

table B.1 continued ...

<i>Question</i>	<i>Category</i>	<i>Rationale and other notes</i>
<ul style="list-style-type: none"> <li>• Are there examples of community cooperation for an energy or non-energy service? If so what is your relationship with it, and how does it work?</li> </ul>	S/R	Discussions around this topic provided useful insights during Stage 1 about service access and transitions.
<ul style="list-style-type: none"> <li>• Please explain your upbringing from childhood till now; where you lived, your education, your travels, and the types of energy services you used as the years progressed.</li> </ul>	S/R	Looking for further external influences of culture and history on behaviour and transitions.



## Appendix C

# Lagos–LEAP Disaggregated Calculation Tables

Tables C.1 to C.4 reveal the 44 household energy consumption profiles developed to explain the manner in which households engage with energy over the timeline of Lagos–LEAP’s modelling, 2010–2043. Within these profiles there are 376 ways in which 23 energy technologies can be used. Table C.1 illustrates the energy consumption calculations for households across all settlement areas (level 1) and income groups (level 2) in accordance with each group’s behaviour under *base* case reticulated electricity supply (level 3) and *base* case consumption efficiency (level 4). Table C.2 presents the changes to energy consumption in the respective groups when there is an increase in consumption efficiency across household groups. Consumption efficiency accounts for any changes in fuel resource, conversion technology, and energy (over)consumption. Tables C.3 and C.4 denote changes in behaviour across all groups when reticulated electricity is supplied for longer hours; with C.3 also considering *base* case (relatively inefficient) consumption efficiency, while C.4 accounts for behaviour under more efficient consumption patterns. Table D.2 in Appendix D presents the sources of data used to develop the database of energy consumption profiles.

### Notes

- a) The first column indicates the household group according to both ‘settlement’ and ‘income’ levels of the model structure (e.g. ‘URBAN HIGH’ denotes; urban (non-slum) settlement, high income group). Together with the prespecified hourly grid availability and private generation use according to Table 8.3.
- b) Subheadings with **yellow** highlight indicate columns that change in each table (according to stated differences in grid availability–hours and/or efficiency of household energy consumption, in terms of energy carrier, conversion technology and behaviour).
- c) Rows highlighted **green** denote a new energy service or new fuel–technology combi-

nation for a household group, relative to the respective group's profile in Table C.1 (which represents the base case).

d) BQ = Boys Quarter (household staff accommodation)

e) The final column "Total consumption (kWh)" is the energy intensity input in LEAP.

**Table C.1: Base provision of reticulated electricity supply across settlement groups with corresponding private generation response across income groups | Base energy consumption efficiency**

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (%) of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
Affected by grid availability hours		Affected by energy consumption efficiency	Affected by grid availability and energy service efficiency					Affected by grid availability and consumption efficiency		Affected by energy consumption efficiency	
URBAN HIGH (6 room average, 3 room BQ) [6hr grid 10hr generator PER DAY]	Space Cooling	Split/Window Air-con	Overuse of Air conditioning with fan support	1.5	12	6570	6570	150%	9855	6	59130
		Standing/Table/Ceiling Fan		0.1	12	438	438	14%	61.32	9	551.88
	Lighting	Halogen/Incandescent	Incandescent/Halogen predominantly, with minor use of CFL/LED, and use of torch lights in between switching and BQs	0.05	7	127.75	127.75	200%	255.5	14	3577
		CFL/LED		0.014	7	35.77	35.77	200%	71.54	6	429.24
		Torch/Recharge-Lantern			7	4.6	4.6	4%	0.184	3	0.552
	Cooking	Kerosene Stove	LPG in homes coupled with kerosene's use in BQs	0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	3	16096.5
		LPG Burner			5	217 kg	2821	100%	2821	2	5642
	Water Heating	Electric Geyser	ASSUMED to be the electric geyser only for calculation purposes		3	3500	3500	400%	14000	3	42000
	Refrigeration	NON-qualified Fridge-Freezer			24	800	800	67%	536	1	536
		NON-qualified Chest Freezer			24	500	500	67%	335	1	335
	Water Pumping	Multi-stage submersible water pump	daily pumping	3	1	1095	1095	100%	1095	1	1095
	Other	Other	Estimated power value	10	1	3650	3650	100%	3650	1	3650

table C.1 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN MEDIUM (4 room average) [6hr grid 5hr generator PER DAY]	Space Cooling	Window Air-con	fan predominantly with air-con based on grid availability	1.5	12	6570	6570	50%	3285	2	6570
		Standing/Table/Ceiling Fan		0.1	12	438	438	80%	350.4	4	1401.6
	Lighting	Halogen/Incandescent	Incandescent/Halogen and Fluorescent. Use of kerosene's lamp and torch/RL when electricity is unavailable	0.05	7	127.75	127.75	80%	102.2	8	817.6
		Fluorescent tube		0.032	7	81.76	81.76	80%	65.408	4	261.632
		Torch/Recharge-Lantern			7	4.6	4.6	5%	0.23	4	0.92
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	5%	25.039	3	75.117
	Cooking	Three Stone stove	Kerosene and LPG burner. 3-S when kerosene's prices sky-rocket and celebrations		6	2340 kg	10530	5%	526.5	1	526.5
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	5365.5	90%	4828.95	2	9657.9
		LPG Burner			5	217 kg	2821	90%	2538.9	1	2538.9
	Refrigeration	NON-qualified Fridge-Freezer	NON-qualified Chest Freezer when any electricity is available		24	800	800	46%	368	1	368
	Other	Other	Estimated power value	6.1	1	2226.5	2226.5	100%	2226.5	1	2226.5
URBAN LOW (2 room average) [6hr grid 3hr generator PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other when electricity is available	0.1	12	438	438	50%	219	1	219
	Lighting	Incandescent	Incandescent combined with Torch/RL and kerosene's	0.06	7	153.3	153.3	50%	76.65	1	76.65
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	3	13.8
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	100%	500.78	1	500.78
	Cooking	Three-stone stove	Kerosene mainly. 3-S when kerosene's prices sky-rocket and smoking/celebrations		6	2340 kg	10530	5%	526.5	1	526.5
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	2	10731
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	4.4	1	1606	1606	100%	1606	1	1606

table C.1 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN POOR (1 room avg) [6hr grid 2hr gen PER DAY]	Lighting	Incandescent	Incandescent combined with Torch/RL and kerosene's	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	2	9.2
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	100%	500.78	2	1001.56
	Cooking	Traditional stove type	Traditional only		6	2340 kg	10530	100%	10530	1	10530
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL HIGH (4 room average) [1hr grid 10hr gen PER DAY]	Space cooling	Standing/Table/Ceiling Fan		0.1	12	438	438	91%	398.58	3	1195.74
	Lighting	Fluorescent tube/Incandescent	Incandescent and Fluorescent. Use of kerosene lamp and torch/RL when electricity is unavailable	0.045	7	114.975	114.975	143%	164.41425	10	1644.1425
		Torch/Recharge-Lantern			7	4.6	4.6	1%	0.046	4	0.184
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	1%	5.0078	1	5.0078
	Cooking	Welded Wood Stove	Kerosene with wood infrequently, mainly for smoking		5	2340 kg	10530	10%	1053	2	2106
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	2	10731
	Refrigeration	NON-qualified Fridge-Freezer	Non-qualified Fridge-freezer and Chest-freezer		24	800	800	45%	360	1	360
		NON-qualified Chest Freezer			24	500	500	45%	225	1	225
	Other	Other	Estimated power value	4.5	1	1642.5	1642.5	100%	1642.5	1	1642.5

table C.1 continued . . .

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL MEDIUM (3 room avg) [1hr grid 5hr gen PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	50%	219	3	657
	Lighting	Incandescent	Incandescent during evenings, kerosene's and RL often	0.06	7	153.3	153.3	71%	108.843	5	544.215
		Torch/Recharge-Lantern			7	4.6	4.6	71%	3.266	2	6.532
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	43%	215.3354	1	215.3354
	Cooking	Welded Wood/Charcoal Stove	Wood with large cooking, kerosene's and		5	2340 kg	10530	100%	10530	2	21060
		Kerosene stove	Wood with Kerosene for small cooking	0.3 litres/hr	5	547.5 litres	5365.5	50%	2682.75	1	2682.75
RURAL LOW (2 room avg) [1hr grid 3hr gen PER DAY]	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
	Space cooling	Table Fan	Use whenever grid electricity is available	0.07	12	306.6	306.6	8%	24.528	1	24.528
	Lighting	Incandescent	Incandescent some of the time. Kerosene most of the time with torch/RL through the night	0.06	7	153.3	153.3	43%	65.919	3	197.757
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	1	4.6
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	100%	500.78	2	1001.56
	Cooking	3-S/Welded Wood/Charcoal Stove	3-S/Welded stove with kerosene's stove		6	2340 kg	10530	100%	10530	2	21060
		Kerosene stove	infrequently	0.3 litres/hr	5	547.5 litres	5365.5	20%	1073.1	1	1073.1
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5

table C.1 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL POOR (1 room avg.) [1hr grid 1hr gen PER DAY]	Lighting	Incandescent	Incandescent some of the time when grid electricity is available. Kerosene most of the time with torch sometimes	0.06	7	153.3	153.3	14%	21.462	2	42.924
		Torch/Local Lamp			7	4.6	4.6	80%	3.68	1	3.68
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	100%	500.78	2	1001.56
	Cooking	3-S/Welded Wood Stove	3-S/Welded stove only		6	2340 kg	10530	100%	10530	2	21060
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3
SLUM MEDIUM (2 room avg.) [3hr grid 3hr gen PER DAY]	Space cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	50%	219	2	438
	Lighting	Incandescent	Incandescent when possible in evenings. Use of Torch/RL with kerosene's less frequently	0.06	7	153.3	153.3	43%	65.919	3	197.757
		Torch/Recharge-Lamp			7	4.6	4.6	100%	4.6	2	9.2
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	10%	50.078	2	100.156
	Cooking	Three-stone stove	Kerosene predominantly. 3-S when kerosene's prices sky-rocket/celebrations		6	2340 kg	10530	10%	1053	1	1053
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	1	5365.5
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when any electricity is available		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	4.3	1	1569.5	1569.5	100%	1569.5	1	1569.5

table C.1 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
SLUM LOW (1 room avg) [3hr grid 2-hour gen PER DAY]	Space Cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	42%	128.772	1	128.772
	Lighting	Incandescent	Incandescent when possible in evenings. Use of Torch/RL with kerosene's less frequently	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Recharge-Lamp			7	4.6	4.6	115%	5.29	1	5.29
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	14%	70.1092	2	140.2184
	Cooking	Three-stone stove	Kerosene predominantly. 3-S when kerosene's prices increase and celebrations		6	2340 kg	10530	10%	1053	1	1053
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	1	5365.5
SLUM POOR (1 room) [3hr grid 1hr gen PER DAY]	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	13%	65	1	65
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
	Lighting	Incandescent	Incandescent when possible in evenings. Torch and kerosene's lamp	0.06	7	153.3	153.3	15%	22.995	2	45.99
		Torch/Local Lamp			7	4.6	4.6	130%	5.98	1	5.98
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	20%	100.156	1	100.156
SLUM POOR (1 room) [3hr grid 1hr gen PER DAY]	Cooking	3-S/Welded/Charcoal stove	3-S/Welded stove only		6	2340 kg	10530	100%	10530	1	10530
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3



**Table C.2: Base provision of reticulated electricity supply across settlement groups with corresponding private generation response across income groups | Efficient energy consumption efficiency**

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
Affected by grid availability hours		Affected by energy consumption efficiency	Affected by grid availability and energy service efficiency					Affected by grid availability and consumption efficiency		Affected by energy consumption efficiency	
URBAN HIGH (6 room average, 3 room BQ) [6hr grid 10hr SOLAR/INVERTER/DIESEL GEN PER DAY]	Space Cooling	Split/Window Air-con	Overuse of Air conditioning with fan support	1.5	12	6570	6570	150%	9855	6	59130
		Standing/Table/Ceiling Fan		0.1	12	438	438	5%	21.9	9	197.1
	Lighting	Halogen/Incandescent	CFL/LED predominantly, with minor use of Incandescent/Halogen, and use of torch lights in between switching and BQs	0.05	7	127.75	127.75	200%	255.5	6	1533
		CFL/LED		0.014	7	35.77	35.77	200%	71.54	14	1001.56
		Torch/Recharge-Lantern			7	4.6	4.6	4%	0.184	3	0.552
	Cooking	LPG Burner			5	217 kg	2821	100%	2821	3	8463
	Water Heating	Electric Geyser	ASSUMED to be the electric geyser only for calculation purposes		3	3500	3500	400%	14000	3	42000
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR fridge freezer and ENERGY STAR chest freezer		24	425	425	67%	284.75	1	284.75
		ENERGY STAR Chest Freezer			24	240	240	67%	160.8	1	160.8
	Other	Other	Estimated power value	10	1	3650	3650	100%	3650	1	3650

table C.2 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN MEDIUM (4 room average) [6hr grid 5hr INVERTER_KeyApp/DIESEL GEN PER DAY]	Space Cooling	Window Air-con Standing/Table/Ceiling Fan	fan predominantly with air-con based on grid availability	1.5 0.1	12 12	6570 438	6570 438	50% 70%	3285 306.6	2 4	6570 1226.4
	Lighting	Halogen/Incandescent	CFL/LED and Fluorescent, with minor use of Hal/Inc. Use of solar lamp and torch/RL when electricity is unavailable	0.05	7	127.75	127.75	80%	102.2	2	204.4
		Fluorescent tube		0.032	7	81.76	81.76	80%	65.408	4	261.632
		CFL/LED		0.014	7	35.77	35.77	80%	28.616	6	171.696
		Torch/Recharge-Lantern			7	4.6	4.6	5%	0.23	3	0.69
		Solar Lamp		0.0015	7	3.8325	3.8325	5%	0.191625	3	0.574875
	Cooking	Three Stone stove	LPG burner predominantly. Kerosene if LPG has problems. 3-S for celebrations	0.3 litres/hr	6	2340 kg	10530	5%	526.5	1	526.5
		Kerosene Stove			5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG Burner			5	217 kg	2821	90%	2538.9	2	5077.8
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR Fridge-Freezer only		24	425	425	46%	195.5	1	195.5
	Other	Other	Estimated power value	6.1	1	2226.5	2226.5	100%	2226.5	1	2226.5
RBAN LOW (2 room average) [6hr grid 3hr generator PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other when electricity is available	0.1	12	438	438	50%	219	1	219
	Lighting	Incandescent	Incandescent combined with Torch/RL and Solar lamp	0.06	7	153.3	153.3	50%	76.65	1	76.65
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	3	13.8
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	1	3.8325
	Cooking	Three-stone stove	LPG for normal cooking. 3-S for smoking/celebrations and cooking support	0.3 litres/hr	6	2340 kg	10530	20%	2106	1	2106
		Kerosene Stove			5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG Burner			5	217 kg	2821	100%	2821	1	2821
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	4.4	1	1606	1606	100%	1606	1	1606

table C.2 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN POOR (1 room avg) [6hr grid 2hr gen PER DAY]	Lighting	Incandescent	Incandescent combined with Torch/RL and Solar lamp	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	2	9.2
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	1	3.8325
	Cooking	Traditional stove type	Traditional and ICS		6	2340 kg	10530	20%	2106	1	2106
		ICS			5	1408 kg	6336	100%	6336	1	6336
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL HIGH (4 room average) [1hr grid 10hr SHS/DIESEL GEN PER DAY]	Space cooling	Standing/Table/Ceiling Fan		0.1	12	438	438	91%	398.58	3	1195.74
	Lighting	Fluorescent tube/Incandescent	CFL/LED and Fluorescent. Use of solar lamp and torch/RL when electricity is unavailable	0.045	7	114.975	114.975	143%	164.41425	3	493.24275
		CFL/LED		0.014	7	35.77	35.77	143%	51.1511	7	358.0577
		Torch/Recharge-Lantern			7	4.6	4.6	1%	0.046	3	0.138
		Solar Lamp		0.0015	7	3.8325	3.8325	1%	0.038325	2	0.07665
	Cooking	Welded Wood Stove	LPG with Welded wood infrequently (celebrations)		5	2340 kg	10530	10%	1053	2	2106
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG stove			5	217 kg	2821	100%	2821	2	5642
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR Fridge-freezer and NON-qualified Chest-freezer		24	425	425	45%	191.25	1	191.25
		NON-qualified Chest Freezer			24	500	500	45%	225	1	225
	Other	Other	Estimated power value	4.5	1	1642.5	1642.5	100%	1642.5	1	1642.5

table C.2 continued . . .

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL MEDIUM (3 room avg) [1hr grid 5hr SHS_small loads/DIESEL GEN PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	50%	219	3	657
	Lighting	Incandescent	Incandescent in the evenings, Solar and RL often	0.06	7	153.3	153.3	71%	108.843	5	544.215
		Torch/Recharge-Lantern			7	4.6	4.6	71%	3.266	1	3.266
		Solar Lamp		0.0015	7	3.8325	3.8325	60%	2.2995	2	4.599
	Cooking	Welded Wood/Charcoal Stove	Welded Wood with large cooking, LPG and ICS for small cooking		5	2340 kg	10530	20%	2106	1	2106
		LPG stove			5	217 kg	2821	50%	1410.5	1	1410.5
		ICS			5	1408 kg	6336	80%	5068.8	1	5068.8
	Refrigeration	ENERGY STAR Chest Freezer	ENERGY STAR Chest Freezer		24	240	240	25%	60	1	60
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL LOW (2 room avg) [1hr grid 3hr gen PER DAY]	Space cooling	Table Fan	Use whenever electricity is available	0.07	12	306.6	306.6	8%	24.528	1	24.528
	Lighting	Incandescent	Incandescent some of the time. Solar and Torch/RL most of the time	0.06	7	153.3	153.3	43%	65.919	3	197.757
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	1	4.6
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	2	7.665
	Cooking	3-S/Welded Wood/Charcoal Stove	3-S/Welded wood and ICS		6	2340 kg	10530	100%	10530	2	21060
		ICS			5	1408 kg	6336	50%	3168	1	3168
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5

table C.2 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL POOR (1 room avg) [1hr grid 1hr gen PER DAY]	Lighting	Incandescent	Incandescent some of the time when electricity is available. Solar and Torch/Local Lamp most of the time	0.06	7	153.3	153.3	14%	21.462	2	42.924
		Torch/Local Lamp			7	4.6	4.6	100%	4.6	1	4.6
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	1	3.8325
	Cooking	3-S/Welded Wood Stove	3-S and ICS		6	2340 kg	10530	100%	10530	1	10530
		ICS			5	1408 kg	6336	50%	3168	1	3168
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3
SLUM MEDIUM (2 room avg) [3hr grid 2hr generator 1hr INVERTER PER DAY]	Space cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	50%	219	2	438
	Lighting	CFL/LED		0.014	7	35.77	35.77	43%	15.3811	3	46.1433
		Torch/Recharge-Lamp			7	4.6	4.6	80%	3.68	2	7.36
		Solar Lamp		0.0015	7	3.8325	3.8325	80%	3.066	1	3.066
	Cooking	Three-stone stove	LPG Burner predominantly. 3-S infrequently (celebrations)		5	2340 kg	10530	10%	1053	1	1053
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG Burner			5	217 kg	2821	100%	2821	1	2821
	Refrigeration	ENERGY STAR Chest Freezer			24	240	240	20%	48	1	48
	Other	Other	Estimated power value	4.3	1	1569.5	1569.5	100%	1569.5	1	1569.5

table C.2 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
SLUM LOW (1 room avg) [3hr grid 2-hour gen PER DAY]	Space Cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	42%	128.772	1	128.772
	Lighting	Incandescent	Incandescent when possible in evenings. Use of Torch/RL and Solar Lamp	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Recharge-Lamp			7	4.6	4.6	100%	4.6	1	4.6
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	1	3.8325
	Cooking	Three-stone stove	LPG predominantly. 3-S infrequently (celebrations)		6	2340 kg	10530	10%	1053	1	1053
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG Burner			5	217 kg	2821	100%	2821	1	2821
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	13%	65	1	65
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
SLUM POOR (1 room) [3hr grid 1hr gen PER DAY]	Lighting	Incandescent	Incandescent when possible in evenings. Torch/Local and Solar lamp	0.06	7	153.3	153.3	15%	22.995	2	45.99
		Torch/Local Lamp			7	4.6	4.6	100%	4.6	1	4.6
		Solar Lamp		0.0015	7	3.8325	3.8325	100%	3.8325	1	3.8325
	Cooking	3-S/Welded/Charcoal stove	3-S/Welded stove and ICS	5 sticks/hour	6	2340 kg	10530	100%	10530	1	10530
		ICS		3 sticks/hr	5	1408 kg	6336	50%	3168	1	3168
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3

**Table C.3: High provision of reticulated electricity supply across settlement groups with corresponding private generation response across income groups | Base energy consumption efficiency**

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
Affected by grid availability hours		Affected by energy consumption efficiency	Affected by grid availability and energy service efficiency					Affected by grid availability and consumption efficiency		Affected by energy consumption efficiency	
URBAN HIGH (6 room average, 3 room BQ) [22hr grid 2hr Generator PER DAY]	Space Cooling	Split/Window Air-con	Overuse of Air conditioning with fan in BQs	1.5	12	6570	6570	150%	9855	6	59130
		Standing/Table/Ceiling Fan		0.1	12	438	438	100%	438	9	3942
	Lighting	Halogen/Incandescent	Incandescent/Halogen predominantly, with minor use of CFL/LED, and very limited use of torch lights in between switching and BQs	0.05	7	127.75	127.75	150%	191.625	18	3449.25
		CFL/LED		0.014	7	35.77	35.77	150%	53.655	18	965.79
		Torch/Recharge-Lantern			7	4.6	4.6	1%	0.046	1	0.046
	Cooking	Kerosene Stove	LPG in homes. Coupled with electric stoves in BQs and less kerosene's use in BQs	0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	3	160.965
		Electric Stove		0.8	5	1460	1460	100%	1460	2	2920
		LPG Burner			5	217 kg	2821	100%	2821	1	2821
	Water Heating	Electric Geyser	ASSUMED to be the electric geyser only for calculation purposes		3	3500	3500	400%	14000	3	42000
	Refrigeration	NON-qualified Fridge-Freezer			24	800	800	100%	800	1	800
		NON-qualified Chest Freezer			24	500	500	100%	500	1	500
	Clothes Washing	Washing Machine	Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Water Pumping	Multi-stage submersible water pump	daily pumping	3	1	1095	1095	100%	1095	1	1095
	Other	Other	Estimated power value	10	1	3650	3650	100%	3650	1	3650

table C.3 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN MEDIUM (4 room average) [22hr grid 0hr generator PER DAY]	Space Cooling	Window Air-con	Air conditioning with fan support	1.5	12	6570	6570	99%	6504.3	2	13008.6
		Standing/Table/Ceiling Fan		0.1	12	438	438	1%	4.38	4	17.52
	Lighting	Halogen/Incandescent	Incandescent/Halogen and Fluorescent. Use of torch/RL when no electricity. Next to no use of kerosene's lamp	0.05	7	127.75	127.75	150%	191.625	8	1533
		Fluorescent tube		0.032	7	81.76	81.76	150%	122.64	4	490.56
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	4	1.84
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	1%	5.0078	1	5.0078
	Cooking	Three Stone stove	Electric Stove and Kerosene Stove. Small use of 3-stone stove during celebrations		6	2340 kg	10530	5%	526.5	1	526.5
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	2463.75	100%	2463.75	1	2463.75
	Refrigeration	NON-qualified Fridge-Freezer			24	800	800	90%	720	1	720
URBAN LOW (2 room average) [22hr grid 0hr generator PER DAY]	Clothes Washing	Washing Machine	Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	6.1	1	2226.5	2226.5	100%	2226.5	1	2226.5
	Space Cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	100%	438	1	438
	Lighting	Incandescent	Incandescent combined with Torch/RL. Minimal use of Kerosene	0.06	7	153.3	153.3	150%	229.95	3	689.85
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	3	1.38
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	1%	5.0078	1	5.0078
	Cooking	Three-stone stove	Electric Stove and Kerosene stove. Small use of 3-stone stove during celebrations		6	2340 kg	10530	10%	1053	1	1053
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	5365.5	50%	2682.75	1	2682.75
	Refrigeration	NON-qualified Fridge-Freezer	NON-qualified Fridge-Freezer		24	800	800	100%	800	1	800
	Clothes Washing	Washing Machine	Shared Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	4.4	1	1606	1606	100%	1606	1	1606



table C.3 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN POOR (1 room avg) [22hr grid 0hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent combined with Torch/RL and kerosene's	0.06	7	153.3	153.3	150%	229.95	2	459.9
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	1	0.46
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	10%	50.078	1	50.078
	Cooking	Traditional stove type	Electric stove and Traditional stove shared use		6	2340 kg	10530	100%	10530	1	10530
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
	Refrigeration	NON-qualified Fridge-Freezer	NON-qualified Fridge-Freezer when electricity is available		24	800	800	100%	800	1	800
	Clothes Washing	Washing Machine	Shared Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL HIGH (4 room average) [6hr grid 10hr gen PER DAY]	Space Cooling	Window Air-con	Overuse of Air-con and fan use	1.5	12	6570	6570	150%	9855	3	29565
		Standing/Table/Ceiling Fan		0.1	12	438	438	14%	61.32	3	183.96
	Lighting	Fluorescent tube/Incandescent	Incandescent and Fluorescent. Use of torch/RL in between switching	0.045	7	114.975	114.975	200%	229.95	10	2299.5
		Torch/Recharge-Lantern			7	4.6	4.6	4%	0.184	4	0.736
	Cooking	Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	100%	5365.5	1	5365.5
		LPG stove			5	217 kg	2821	100%	2821	1	2821
	Refrigeration	NON-qualified Fridge-Freezer	Non-qualified Fridge-freezer and Chest-freezer		24	800	800	67%	536	1	536
		NON-qualified Chest Freezer			24	500	500	67%	335	1	335
	Other	Other	Estimated power value	4.5	1	1642.5	1642.5	100%	1642.5	1	1642.5

table C.3 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL MEDIUM (3 room avg) [6hr grid 5hr gen PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other more often	0.1	12	438	438	90%	394.2	3	1182.6
	Lighting	Incandescent	Incandescent use most of the evenings with generator. Torch/RL use when no electricity of any form	0.06	7	153.3	153.3	71%	108.843	5	544.215
		Torch/Recharge-Lantern			7	4.6	4.6	30%	1.38	3	4.14
	Cooking	Welded Wood/Charcoal Stove	Wood stove with large cooking. Kerosene and some LPG for everyday cooking		5	2340 kg	10530	20%	2106	2	4212
		LPG stove			5	217 kg	2821	20%	564.2	1	564.2
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	90%	4828.95	1	4828.95
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer		24	500	500	45%	225	1	225
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL LOW (2 room avg) [6hr grid 3hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	75%	229.95	2	459.9
	Lighting	Incandescent	Incandescent whenever any electricity is available. Torch/RL most of the time and lower use of kerosene's	0.06	7	153.3	153.3	40%	61.32	3	183.96
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	2	9.2
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	20%	100.156	1	100.156
	Cooking	3-S/Welded Wood/Charcoal Stove	3-S/Welded stove with kerosene's stove infrequently		6	2340 kg	10530	100%	10530	1	10530
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	20%	1073.1	1	1073.1
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5

table C.3 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL POOR (1 room avg) [6hr grid 2hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	67%	205.422	1	205.422
	Lighting	Incandescent	Incandescent whenever any electricity is available. Torch/RL most of the time and lower use of kerosene's	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Local Lamp			7	4.6	4.6	114%	5.244	1	5.244
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	20%	100.156	2	200.312
	Cooking	3-S/Welded Wood Stove	3-S/Welded stove only	5 sticks/hour	6	2340 kg	10530	100%	10530	2	21060
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3
SLUM MEDIUM (2 room avg) [12hr grid 3hr gen PER DAY]	Space cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	100%	438	2	876
	Lighting	Incandescent	Incandescent/Halogen. Use of torch/RL when no electricity. Next to no use of kerosene's lamp	0.06	7	153.3	153.3	100%	153.3	3	459.9
		Torch/Recharge-Lamp			7	4.6	4.6	90%	4.14	2	8.28
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	1%	5.0078	2	10.0156
	Cooking	LPG stove	NON-qualified Chest Freezer when any electricity is available		5	217 kg	2821	80%	2256.8	1	2256.8
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	80%	4292.4	1	4292.4
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when any electricity is available		24	500	500	63%	315	1	315
	Other	Other	Estimated power value	4.3	1	1569.5	1569.5	100%	1569.5	1	1569.5

table C.3 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
SLUM LOW (1 room avg) [12hr grid 2-hour gen PER DAY]	Space Cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent when electricity is available. Use of Torch/RL	0.06	7	153.3	153.3	100%	153.3	2	306.6
		Torch/Recharge-Lamp			7	4.6	4.6	100%	4.6	2	9.2
	Cooking	Electric Stove	Electric Stove when grid is available	0.8	5	1460	1460	80%	1168	1	1168
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	90%	4828.95	1	4828.95
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	50%	250	1	250
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
SLUM POOR (1 room) [12hr grid 1hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent when electricity is available. Torch and kerosene's lamp	0.06	7	153.3	153.3	70%	107.31	2	214.62
		Torch/Local Lamp			7	4.6	4.6	114%	5.244	1	5.244
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	100%	500.78	1	500.78
	Cooking	3-S/Welded/Charcoal stove	3-S/Welded stove and Electric stove when grid electricity is available		6	2340 kg	10530	100%	10530	1	10530
		Electric Stove		0.8	5	1460	1460	70%	1022	1	1022
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3

**Table C.4: High provision of reticulated electricity supply across settlement groups with corresponding private generation response across income groups | Efficient energy consumption efficiency**

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
Affected by grid availability hours		Affected by energy consumption efficiency	Affected by grid availability and energy service efficiency					Affected by grid availability and consumption efficiency		Affected by energy consumption efficiency	
URBAN HIGH (6 room average, 3 room BQ) [22hr grid 2hr INVERTER PER DAY]	Space Cooling	Split/Window Air-con	Overuse of Air conditioning with fan in BQs	1.5	12	6570	6570	150%	9855	6	59130
		Standing/Table/Ceiling Fan		0.1	12	438	438	100%	438	9	3942
	Lighting	Halogen/Incandescent	CFL/LED predominantly, with minor use of Incandescent/Halogen, and very limited use of torch lights in between switching	0.05	7	127.75	127.75	150%	191.625	10	1916.25
		CFL/LED		0.014	7	35.77	35.77	150%	53.655	26	1395.03
		Torch/Recharge-Lantern			7	4.6	4.6	1%	0.046	1	0.046
	Cooking	Kerosene Stove	LPG in homes. Coupled with electric stoves and limited kerosene's when no electricity in BQs	0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		Electric Stove		0.8	5	1460	1460	100%	1460	2	2920
		LPG Burner			5	217 kg	2821	100%	2821	1	2821
	Water Heating	Electric Geyser	ASSUMED to be the electric geyser only for calculation purposes		3	3500	3500	400%	14000	3	42000
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR fridge freezer and ENERGY STAR chest freezer		24	425	425	100%	425	1	425
		ENERGY STAR Chest Freezer			24	240	240	100%	240	1	240
	Clothes Washing	Washing Machine	Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	10	1	3650	3650	100%	3650	1	3650

table C.4 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN MEDIUM (4 room average) [22hr grid 0hr generator PER DAY]	Space Cooling	Window Air-con	Air conditioning with fan support	1.5	12	6570	6570	99%	6504.3	2	13008.6
		Standing/Table/Ceiling Fan		0.1	12	438	438	1%	4.38	4	17.52
	Lighting	Fluorescent tube		0.032	7	81.76	81.76	150%	122.64	4	490.56
		CFL/LED		0.014	7	35.77	35.77	150%	53.655	8	429.24
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	4	1.84
	Cooking	Three Stone stove	Electric Stove and minimal use of Kerosene when no electricity. Small use of 3-stone stove during celebrations		6	2340 kg	10530	5%	526.5	1	526.5
		Electric Stove		0.8	5	1460	1460	100%	1460	2	2920
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	5365.5	2%	107.31	1	107.31
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR Fridge-Freezer only		24	425	425	90%	382.5	1	382.5
	Clothes Washing	Washing Machine	Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	6.1	1	2226.5	2226.5	100%	2226.5	1	2226.5
URBAN LOW (2 room average) [22hr grid 0hr generator PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	100%	438	1	438
	Lighting	Incandescent	Incandescent and CFL/LED combined with Torch/RL if needed	0.06	7	153.3	153.3	150%	229.95	2	459.9
		CFL/LED		0.014	7	35.77	35.77	150%	53.655	2	107.31
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	3	1.38
	Cooking	Three-stone stove	Electric Stove and minimal use of Kerosene stove when no electricity. Small use of 3-stone stove during celebrations		6	2340 kg	10530	5%	526.5	1	526.5
		Electric Stove		0.8	5	1460	1460	100%	1460	2	2920
		Kerosene Stove		0.3 litres/hr	5	547.5 litres	5365.5	2%	107.31	1	107.31
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR Fridge-Freezer		24	425	425	100%	425	1	425
	Clothes Washing	Washing Machine	Shared Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	4.4	1	1606	1606	100%	1606	1	1606

table C.4 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
URBAN POOR (1 room avg) [22hr grid 0hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent combined with Torch/RL if needed	0.06	7	153.3	153.3	150%	229.95	2	459.9
		Torch/Recharge-Lantern			7	4.6	4.6	10%	0.46	2	0.92
	Cooking	Traditional stove type	Electric stove and Traditional stove shared use - no need for much smoking due to refrigerator		6	2340 kg	10530	85%	8950.5	1	8950.5
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
	Refrigeration	NON-qualified Fridge-Freezer	NON-qualified Fridge-Freezer when electricity is available		24	800	800	100%	800	1	800
	Clothes Washing	Washing Machine	Shared Washing Machine use	0.52	2	1.04	1.04	100%	1.04	1	1.04
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL HIGH (4 room average) [6hr grid 10hr SHS/INVERTER_keyAPP PER DAY]	Space Cooling	Window Air-con	Air-con when grid electricity is available and fan use when no grid	1.5	12	6570	6570	50%	3285	3	9855
		Standing/Table/Ceiling Fan		0.1	12	438	438	90%	394.2	4	1576.8
	Lighting	Fluorescent tube/Incandescent	CFL/LED and Fluorescent. Use of solar lamp and torch/RL in between switching	0.045	7	114.975	114.975	200%	229.95	4	919.8
		CFL/LED		0.014	7	35.77	35.77	200%	71.54	6	429.24
		Torch/Recharge-Lantern			7	4.6	4.6	2%	0.092	2	0.184
		Solar Lamp		0.0015	7	3.8325	3.8325	2%	0.07665	2	0.1533
	Cooking	Welded Wood Stove	LPG with Welded wood infrequently (celebrations) kerosene's stove for support		5	2340 kg	10530	5%	526.5	1	526.5
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		LPG stove			5	217 kg	2821	100%	2821	2	5642
	Refrigeration	ENERGY STAR Fridge-Freezer	ENERGY STAR Fridge-freezer and Non-Qualified Chest-freezer		24	425	425	67%	284.75	1	284.75
		NON-qualified Chest Freezer			24	500	500	67%	335	1	335
	Other	Other	Estimated power value	4.5	1	1642.5	1642.5	100%	1642.5	1	1642.5

table C.4 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL MEDIUM (3 room avg) [6hr grid 5hr gen PER DAY]	Space Cooling	Standing/Table/Ceiling Fan	One or the other more often	0.1	12	438	438	90%	394.2	3	1182.6
	Lighting	Incandescent	Incandescent and CFL/LED use most of the evenings with generator. Torch/RL use when no electricity of any form	0.06	7	153.3	153.3	71%	108.843	2	217.686
		CFL/LED		0.014	7	35.77	35.77	71%	25.3967	3	76.1901
		Torch/Recharge-Lantern			7	4.6	4.6	30%	1.38	3	4.14
	Cooking	Welded Wood/Charcoal Stove	Welded stove with large cooking. LPG and ICS for everyday cooking		5	2340 kg	10530	30%	3159	1	3159
		LPG stove			5	217 kg	2821	80%	2256.8	1	2256.8
		ICS			5	1408 kg	6336	90%	5702.4	1	5702.4
	Refrigeration	ENERGY STAR Chest Freezer	ENERGY STAR Chest Freezer		24	240	240	45%	108	1	108
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5
RURAL LOW (2 room avg) [6hr grid 3hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	75%	229.95	2	459.9
	Lighting	Incandescent	Incandescent and CFL/LED whenever any electricity is available. Torch/RL most of the time	0.06	7	153.3	153.3	40%	61.32	1	61.32
		CFL/LED		0.014	7	35.77	35.77	40%	14.308	2	28.616
		Torch/Recharge-Lantern			7	4.6	4.6	100%	4.6	2	9.2
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	1%	5.0078	1	5.0078
	Cooking	3-S/Welded Wood/Charcoal Stove	3-S/Welded stove and ICS. Kerosene just in case		6	2340 kg	10530	90%	9477	1	9477
		Kerosene stove		0.3 litres/hr	5	547.5 litres	5365.5	1%	53.655	1	53.655
		ICS			5	1408 kg	6336	100%	6336	1	6336
	Refrigeration	NON-qualified Chest Freezer	NON-qualified Chest Freezer when grid electricity is available		24	500	500	25%	125	1	125
	Other	Other	Estimated power value	0.1	1	36.5	36.5	100%	36.5	1	36.5



table C.4 continued ...

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
RURAL POOR (1 room avg.) [6hr grid 2hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	67%	205.422	1	205.422
	Lighting	Incandescent	Incandescent whenever any electricity is available. Torch/RL most of the time	0.06	7	153.3	153.3	30%	45.99	2	91.98
		Torch/Recharge-Lamp			7	4.6	4.6	114%	5.244	1	5.244
		Kerosene Lamp		0.02 litres/hr	7	51.1 litres	500.78	20%	100.156	2	200.312
	Cooking	3-S/Welded Wood Stove	3-S and ICS	5 sticks/hour	6	2340 kg	10530	100%	10530	1	10530
		ICS		3 sticks/hr	5	1408 kg	6336	100%	6336	1	6336
	Other	Other	Estimated power value	0.02	1	7.3	7.3	100%	7.3	1	7.3
SLUM MEDIUM (2 room avg.) [12h grid 3hr gen PER DAY]	Space cooling	Standing/Table/Ceiling Fan	One or the other	0.1	12	438	438	100%	438	2	876
	Lighting	Incandescent	CFL/LED mainly. Use of torch/RL when no electricity and through the night	0.06	7	153.3	153.3	100%	153.3	1	153.3
		CFL/LED		0.014	7	35.77	35.77	100%	35.77	2	71.54
		Torch/Recharge-Lamp			7	4.6	4.6	90%	4.14	2	8.28
	Cooking	LPG stove			5	217 kg	2821	80%	2256.8	1	2256.8
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
	Refrigeration	ENERGY STAR Chest Freezer			24	240	240	63%	151.2	1	151.2
	Other	Other	Estimated power value	4.3	1	1569.5	1569.5	100%	1569.5	1	1569.5

table C.4 continued . . .

Electricity supply	Energy service	Energy conversion technology	Nature of use	Power (kW unless otherwise stated)	Useful Hours per day	Useful annual consumption per appliance (kWh unless otherwise stated)	Useful annual consumption per appliance (kWh)	Application (% of appliance use relative to useful hours per day)	Actual consumption per appliance (adjusted for application)	Appliance number per household	Total annual consumption (kWh) (adjusted for no. of appliances)
SLUM LOW (1 room avg.) [12hr grid 2-hour gen PER DAY]	Space Cooling	Table Fan	One or the other when grid is available	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent and CFL/LED when electricity is available. Use of Torch/RL when not available and through the night	0.06	7	153.3	153.3	100%	153.3	1	153.3
		CFL/LED		0.014	7	35.77	35.77	100%	35.77	1	35.77
		Torch/Recharge-Lamp			7	4.6	4.6	100%	4.6	2	9.2
	Cooking	Three-stone stove	Electric stove when grid is available as well as 3-S stove when grid is not available and support		6	2340 kg	10530	50%	5265	1	5265
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
	Refrigeration	ENERGY STAR Chest Freezer			24	240	240	50%	120	1	120
Other	Other	Estimated power value		0.1	1	36.5	36.5	100%	36.5	1	36.5
SLUM POOR (1 room) [12hr grid 1hr gen PER DAY]	Space cooling	Standing/Table Fan	One or the other	0.07	12	306.6	306.6	100%	306.6	1	306.6
	Lighting	Incandescent	Incandescent when electricity is available. Torch/RL when not available	0.06	7	153.3	153.3	70%	107.31	2	214.62
		Torch/Recharge-Lamp			7	4.6	4.6	114%	5.244	2	10.488
	Cooking	3-S/Welded/Charcoal stove	Electric stove when grid is available as well as 3-S stove when grid is not available and support		6	2340 kg	10530	50%	5265	1	5265
		Electric Stove		0.8	5	1460	1460	100%	1460	1	1460
Other	Other	Estimated power value		0.02	1	7.3	7.3	100%	7.3	1	7.3

## Appendix D

# Lagos–LEAP Data Sources

Tables (D.1 + D.2) and (D.3 + D.4) respectively present the full data sources used in the preparation of Lagos–LEAP’s energy consumption database/structure and the generation of the annual household percentage share data at levels 1, 2 and 4 of the model structure.

**Table D.1:** Lagos-LEAP model data sources: *Social, economic, and technology characteristics data*

	TYPE OF DATA	BASE YEAR DATA SOURCE(S)	GROWTH AND END YEAR DATA SOURCE(S)
<b>Household population</b>	Population #hh	UN-Habitat 2013	
	Population growth forecast %total		UN-Habitat 2013, and estimation
	Avg household size per location and income group #persons	Robertson et al. 2011, LBS 2013	
<b>Type of settlement</b>	Local government population #persons	LBS 2010	
	Local government classification confirmation (settlement type - urban, rural, slum)	World Bank 2006, Agbola & Agunbiade 2009, LBS 2010, Filani 2012, NBS 2012, Lukeman 2014	
	Settlement type population distribution %share	LBS 2010, 2013	Estimated for each scenario using historical data (see Tables D.3 and D.4)
<b>Income distribution</b>	Avg Income groups confirmation	Hammond et al. 2007, LBS 2010, Accenture 2011b, NBS 2012, MTI 2013, fieldwork data	
	Income group distribution %share	LBS 2010	Estimated for each scenario using historical data (see Tables D.3 and D.4)
<b>Reticulated electricity availability and private electricity generation</b>	Avg urban, slum, and rural reticulated electricity #hours	LBS 2013, Ikeja DISCO 2013, MTI 2013, UNDP 2013, fieldwork data	Assumed based on: Fridley et al. 2013, researcher's knowledge, stakeholder interviews, and other country experiences
	Avg urban, slum, and rural private generation #hours	LBS 2013, MTI 2013, fieldwork data	Assumed based on: researcher's knowledge and stakeholder interviews

table D.1 continued . . .

	TYPE OF DATA	BASE YEAR DATA SOURCE(S)	GROWTH AND END YEAR DATA SOURCE(S)
	Base and High reticulated electricity availability distribution %share	Assumed 0% for high category	Model assumption and sensitivity analysis
Energy consumption efficiency	urban new technology adoption %share	Assumed 0% for efficient category	Estimated for each scenario using historical data (see Tables D.3 and D.4)
	rural new technology adoption %share	Assumed 0% for efficient category	Estimated for each scenario using historical data (see Tables D.3 and D.4)

**Table D.2:** Lagos–LEAP model data sources: *Technology and consumption data*

	TYPE OF DATA	BASE YEAR DATA SOURCE(S)	GROWTH AND END YEAR DATA SOURCE(S)
<b>Base reticulated availability_Base technologies/consumption (energy intensities)</b>	urban, slum and rural energy service profiles per income group (service and technology composition, nature of use)	UN-Habitat 2008, Accenture 2011 <i>b</i> , LBS 2013, MTI 2013, fieldwork data	
	technology stock, technology loads (kW), technology amount per household (based on avg number of rooms per income group)	Mills 2003, Howells et al. 2005, Uyigue et al. 2009, UN-Habitat 2008, USDOE 2010, Robertson et al. 2011, Accenture 2011 <i>a</i> , NBS 2012, LBS 2013, Upadhyay et al. 2013, UNDP 2013, fieldwork data	
	Useful hours per day #hours, actual hours per day #hours	Accenture 2011 <i>a</i> , LBS 2013, MTI 2013, fieldwork data	
<b>Base reticulated availability_Efficient technologies/consumption (energy intensities)</b>	urban, slum and rural energy service profiles per income group (service and technology composition, nature of use)		Assumed with consult of: Barnes et al. 2004, Cervigni et al. 2013, stakeholder meetings, and fieldwork insights
	technology stock, technology loads (kW), technology amount per household (based on avg number of rooms per income group)	Same sources found in Base distributed generation_Base technologies category, in addition to IEA 2014 <i>a,b</i> , REN21 2015	
	Useful hours per day #hours, actual hours per day #hours		Assumed based on: researcher's knowledge and fieldwork insights
<b>High reticulated availability_Base technologies/consumption (energy intensities)</b>	urban, slum and rural energy service profiles per income group (service and technology composition, nature of use)		Assumed with consult of: Barnes et al. 2004, Cervigni et al. 2013, stakeholder meetings, and fieldwork insights

table D.2 continued ...

	TYPE OF DATA	BASE YEAR DATA SOURCE(S)	GROWTH AND END YEAR DATA SOURCE(S)
	technology stock, technology loads (kW), technology amount per household (based on avg number of rooms per income group)		No assumptions made for technological breakthroughs. Used current technology performance attributes of efficient technologies. Sources found in Base distributed generation_Base technologies category, in addition to IEA 2014 <i>a,b</i> , REN21 2015
	Useful hours per day #hours, actual hours per day #hours		Assumed based on: researcher's knowledge and fieldwork insights
<b>High reticulated availability_Efficient technologies/consumption (energy intensities)</b>	urban, slum and rural energy service profiles per income group (service and technology composition, nature of use)		Assumed with consult of: Barnes et al. 2004, Cervigni et al. 2013, stakeholder meetings, and fieldwork insights
	technology stock, technology loads (kW), technology amount per household (based on avg number of rooms per income group)		No assumptions made for technological breakthroughs. Used current technology performance attributes of efficient technologies. Sources found in Base distributed generation_Base technologies category, in addition to IEA 2014 <i>a,b</i> , REN21 2015
	Useful hours per day #hours, actual hours per day #hours		Assumed based on: researcher's knowledge and fieldwork insights

**Table D.3:** Historical data sources for variable parameter correlation estimations and input data generation: *Activity dependent variables*

Category– levels	Subcategory	<i>Model Input</i>	<i>Regression information</i>				
		Annual share	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
Settlement (Level 1)	Total urban population	regression estimate	urbanization level	Lagos	1991–2010	NBS 2012, UN-Habitat 2013	Calculated back to 1991 using local government population data, cross-checked with UN estimates for Lagos urban agglomeration
	Rural population	remainder of total population share	-				
	Urban non-slum population	remainder of urban population share	-				
	Urban slum population	regression estimate	proportion of urban in slum	Nigeria	1996–2013	UN-Habitat 2013	Lagos represents major slum indicators in Nigeria, and the slum proportions between 2006 and 2010 mirror closely. Both 2010 and 1995 levels are roughly the same. Consecutive annual data, only available for Nigeria, was used



table D.3 continued ...

Category– levels	Subcategory	<i>Model Input</i>	<i>Regression information</i>				
		Annual share	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
Income distribution (Level 2)	High	assumed for model					
	Medium	remainder of income distribution share	-				
	Low	remainder of 'low+poor' share minus 'poor' share	-				
	Low + Poor	regression estimate	proportion of population living under \$2 per day	Nigeria	1996–2010	World Bank 2018 <sup>f</sup>	
	Poor	regression estimate	proportion of population living under \$1.25 per day	Nigeria	1996–2010	World Bank 2018 <sup>f</sup>	
Distributed electricity availability (Level 3)	Base availability	remainder of availability share					

table D.3 continued ...

Category– levels	Subcategory	<i>Model Input</i>	<i>Regression information</i>				
		Annual share	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
	High availability	assumed for model					
358	Energy consumption efficiency (Level 4)	Urban Inefficient base energy consumption efficiency	remainder of urban energy consumption efficiency share	-			
		Urban efficient energy consumption efficiency	regression estimate	urban white goods ownership	China	1981–2011	Fridley et al. 2013
		Rural Inefficient base energy consumption efficiency	remainder of rural energy consumption efficiency share	-			
		Rural efficient energy consumption efficiency	regression estimate	rural white goods ownership	China	1985–2011	Fridley et al. 2013

**Table D.4:** Historical data sources for variable parameter correlation estimations and input data generation: *Scenario driver independent variables*

External environment drivers	<i>Regression information</i>				
	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
Administrative capacity	regulatory quality estimate	Nigeria	1996–2013	World Bank 2018 <i>h</i>	Lagos’ ability to regulate its state has increased in recent years which can be seen in its internal revenue generation processes, however other aspects of regulation which impact its socio-economic and energy system such as border controls, and quality standards are indicated at the national level. Further, its competence or lack of, in regulating urban growth has tracked and continues to track national regulatory competence.

table D.4 continued . . .

External environment drivers	<i>Regression information</i>				
	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
Infrastructure	gross fixed capital formation	Nigeria	1996–2013	World Bank 2018 <sup>f</sup>	The development of critical infrastructure is an aspect of development the state is not entirely independent on, while the state has used private partnerships for some projects, it still requires federal level projects to be channelled to the state. Nevertheless, it is expected that the influence of changes in Lagos state's infrastructure investments can be captured by national level data.
Economic transformation and productivity	manufactures exports	Nigeria	1991–2010	World Bank 2018 <sup>f</sup>	Lagos contributes highly to the industrial metrics of Nigeria, and is expected to be central to growth in industry within the country, therefore making it reasonable to adopt national indications of change for estimation

table D.4 continued . . .

External environment drivers	<i>Regression information</i>				
	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
	agriculture value added	Nigeria	1991–2010	World Bank 2018 <i>f</i>	Agriculture is practised right across the various zones of Nigeria, although at greater scale in the north. However, the scope for and potential influence of adding value per worker in the sector is similar right across the country, given the high presence of small holder farmers and a historical lack of technical capability in farm processes. A national indicator is therefore useful for estimates
	GDP per capita, PPP	Nigeria	1996–2010	World Bank 2018 <i>f</i>	Annual growth in GDP for Lagos have closely matched national changes, given that Lagos contributes largely to the Nigerian economy, making it reasonable to utilise national indicators
Law enforcement	rule of Law estimate	Nigeria	1996–2013	World Bank 2018 <i>h</i>	The practice and capability to enforce rule of law has historically had no major distinctions between federal and state levels.

table D.4 continued . . .

External environment drivers	<i>Regression information</i>				
	Indicator	Country/State data	Period	Data source	Notes (data treatment and considerations)
Economic formality	vulnerable employment	Sub-Saharan Africa	1996–2010	ILO 2015	Vulnerable employment data was unavailable for both Lagos and Nigeria, which required the use of SSA averages.
Domestic purchasing power	growth change in GNI per capita, PPP	China	1981–2011	World Bank 2018 <i>f</i>	China time-series historical data was used to estimate parameters due to corresponding China data utilised at level 4 of the model structure
	growth change in national price level	China	1981–2011	World Bank 2018 <i>f</i>	same as previous note

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